SEASOAR and CTD Observations During a COARE Surveys Cruise, W9211C, 22 January to 22 February 1993.

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Introduction

An international Coupled Ocean-Atmosphere Response Experiment (COARE) was conducted in the warm-pool region of the western equatorial Pacific Ocean over a four-month period from November 1992 through February 1993 (Webster and Lukas, 1992). Most of the oceanographic and meteorological observations were concentrated in the Intensive Flux Array (IFA) centered at 1° 45'S, 156°00'E. As part of this experiment, the R/V Wecoma conducted three survey cruises on the R/V Wecoma; each cruise included measurements of the temperature, salinity and velocity distribution in the upper 300 m of the ocean, and continuous meteorological measurements of wind, air temperature, humidity, etc. Most of these measurements were along a butterfly pattern that was sampled repeatedly during the three COARE Surveys cruises, W9211A and W9211B, and W9211C.

Coordinates of the Standard Butterfly Pattern were chosen to measure zonal and meridional gradients across the center of the IFA, spanning the profiling current meter array, while avoiding moorings and stationary ships without frequent deviations from our track (Figure 1). The standard coordinates of the butterfly apexes are:

SBN	1°14'S	156°06'E
SBS	2°26'S	156°06'E
SBW	1°50'S	155°30'E
SBE	1°50'S	156°42'E,

and sampling was done sequentially along the track joining these four points, i.e. along a meridional section (N2S) from SBN to SBS, a diagonal section (S2W) from SBS to SBW, a zonal section (W2E) from SBW to SBE, and a diagonal section (E2N) from SBE to SBN to complete the pattern. Along this track, we measured the upper ocean temperature and salinity by means of a towed undulating Seasoar vehicle (Figure 2) equipped with a SeaBird CTD system, while underway at 7-8 knots. CTD casts were made at the beginning and end of each tow, primarily to check calibration of the Seasoar sensors. Water velocity along the ship's track was measured by means of the ship-borne acoustic Doppler current profiler.

This report summarizes the Seasoar and CTD observations from Wecoma's third COARE Surveys cruise, W9211C. It also provides a cruise narrative, and a brief description of the data processing procedures.

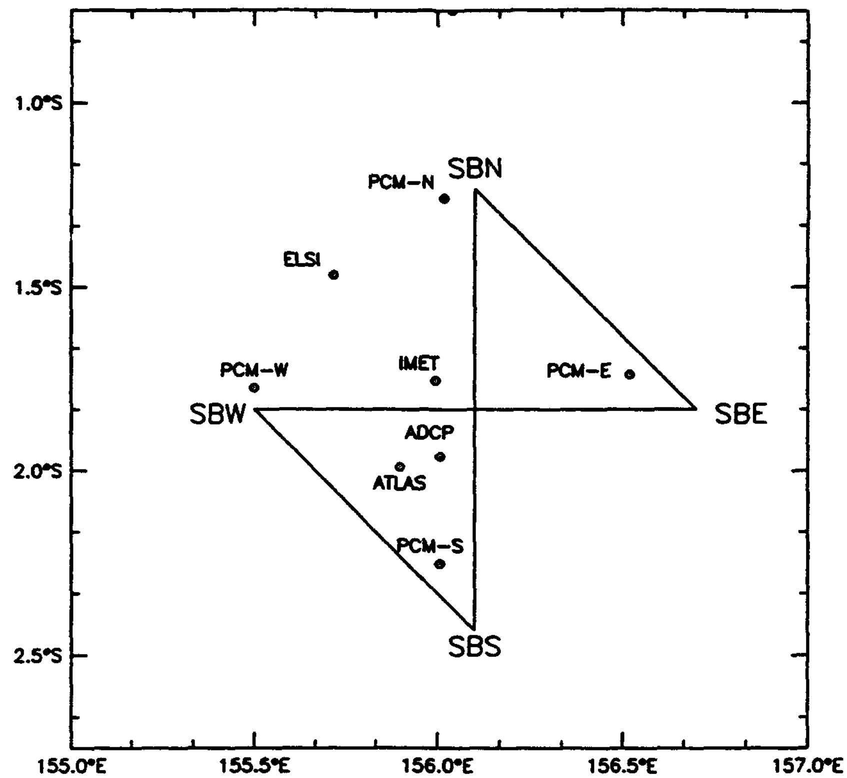

Figure 1. The Standard Butterfly Pattern in relation to the moorings of the COARE Intensive Flux Array.

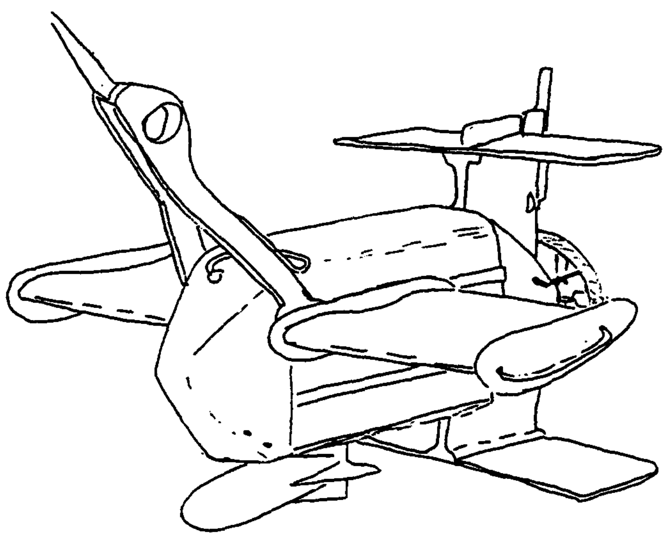

Figure 2. Sketch of the Seasoar vehicle used during W9211C.

Table 1. Summary of CTD stations during W9211C.

Date	Time (UTC)	Station No.	Latitude	Longitude	Wind Dir. (T)	Wind Spd. (kts)	Atmos. P. (mbar)
26 Jan	1439	1	03°07.4'N	156°07.1'E	260	10	1005.8
27 Jan	0725	2	01°14.0'S	156°06.0'	310	8	1006.8
29 Jan	0540	3	02°27.2'	156°07.8'	300	9	1007.2
29 Jan	0750	4	02°22.0'	156°02.0	320	11	1008.3
3 Feb	2035	5	01°51.3'	155°30.3'	340	20	1010.8
3 Feb	2159	6	01°51.2'	155°34.1'	350	19	1012.3
7 Feb	0003	7	01°17.2'	156°09.6'	340	10	1010.7
7 Feb	1930	8	01°14.0'	156°06.0'	340	12	1008.4
12 Feb	2059	9	02°00.4'	155°40.4'	335	13	1009.6
12 Feb	2320	10	02°00.3'	155°40.7'	330	15	1010.0
13 Feb	0440	11	01°59.3'	155°43.4'	310	10	1007.2
16 Feb	2130	12	00°08.7'S	156°06.1'E	070	10	1010.3

Table 2. Instruments and sensors used for CTD, Seasoar, and underway salinity sampling, W9211C, and date of most recent manufacturer's pre-cruise calibration.

System (Instrument)	Sensor		Pre-Cruise Calibration Date
CTD (SBE *9/11 plus* SN 0256)	P	50130	5 Mar 92
	T1	1364	6 Oct 92 (modified 2 Dec 92)
	T2	1366	6 Oct 92 (modified 2 Dec 92)
	C1	1018	16 Sept 92
	C2	1021	16 Sept 92
Seasoar (SBE *9/11 plus* SN 2843)			
(Tows 1-6)	P	39107	5 Mar 92
	C1	1030	17 Apr 92
	C2	1041	24 Apr 92
(Tows 1-3)	T1	1367	27 Mar 92 (modified 2 Dec 92)
	T2	1369	27 Mar 92 (modified 2 Dec 92)
(Tows 4-6)	T1	997	6 Oct 92 (modified 2 Dec 92)
	T2	1384	6 Oct 92 (modified 2 Dec 92)
5-m Intake (MIDAS)	T	854	10 Aug 90
	C	1070	23 Sept 92

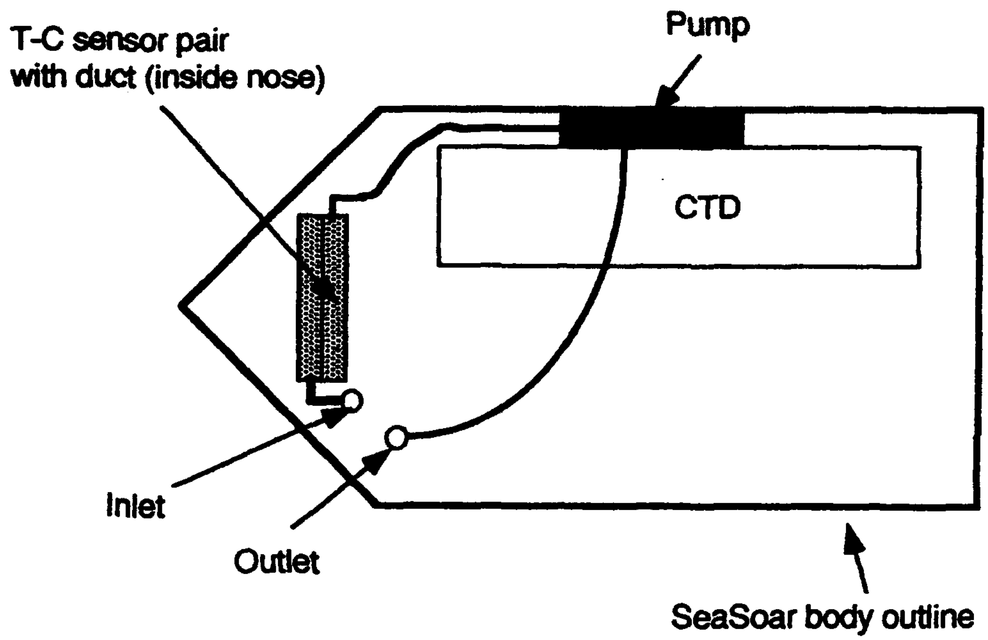

Figure 3. Schematic of the plumbing of the ducted T/C sensors inside the Seasoar vehicle. Primary sensor inlet and outlet ports were on the starboard side of the Seasoar nose; secondary sensor ports were on the port side. During Tow 2, both ducts were disconnected at the outlet from the pump; during Tow 4, the secondary sensor duct was disconnected at the outlet port.

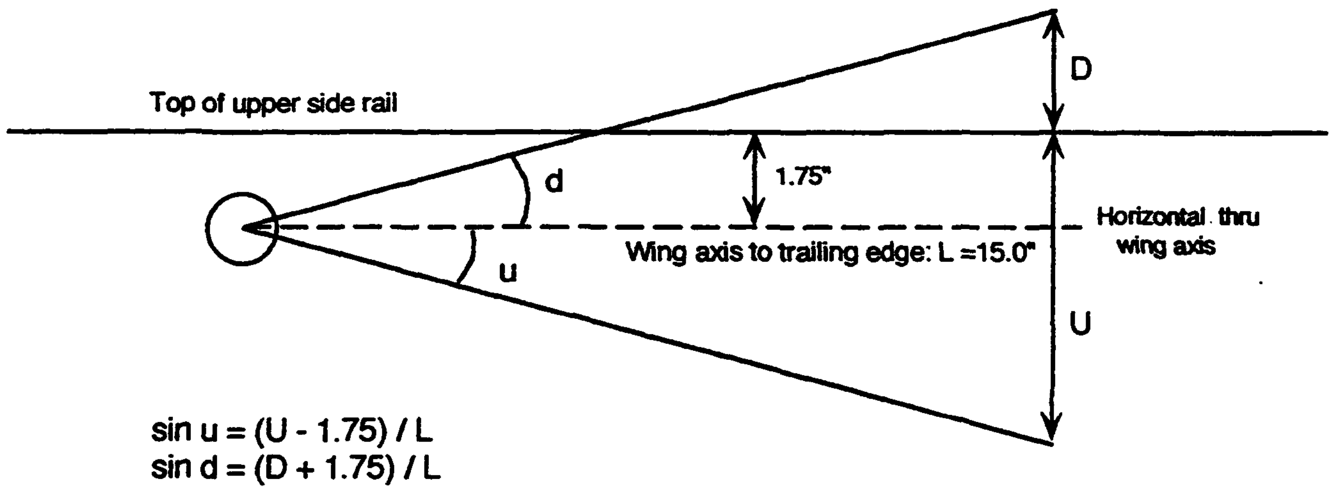

Figure 4. Schematics of Seasoar wing angle settings. During Tows 1 and 2, the value of D was $2^3/_8$" and U was $7^5/_8$", yielding an up-angle of 23° and a down-angle of 16°. During Tows 3 through 6, D was $2^5/_8$" and U was $7^3/_8$", yielding an up-angle of 22° and a down-angle of 17°.

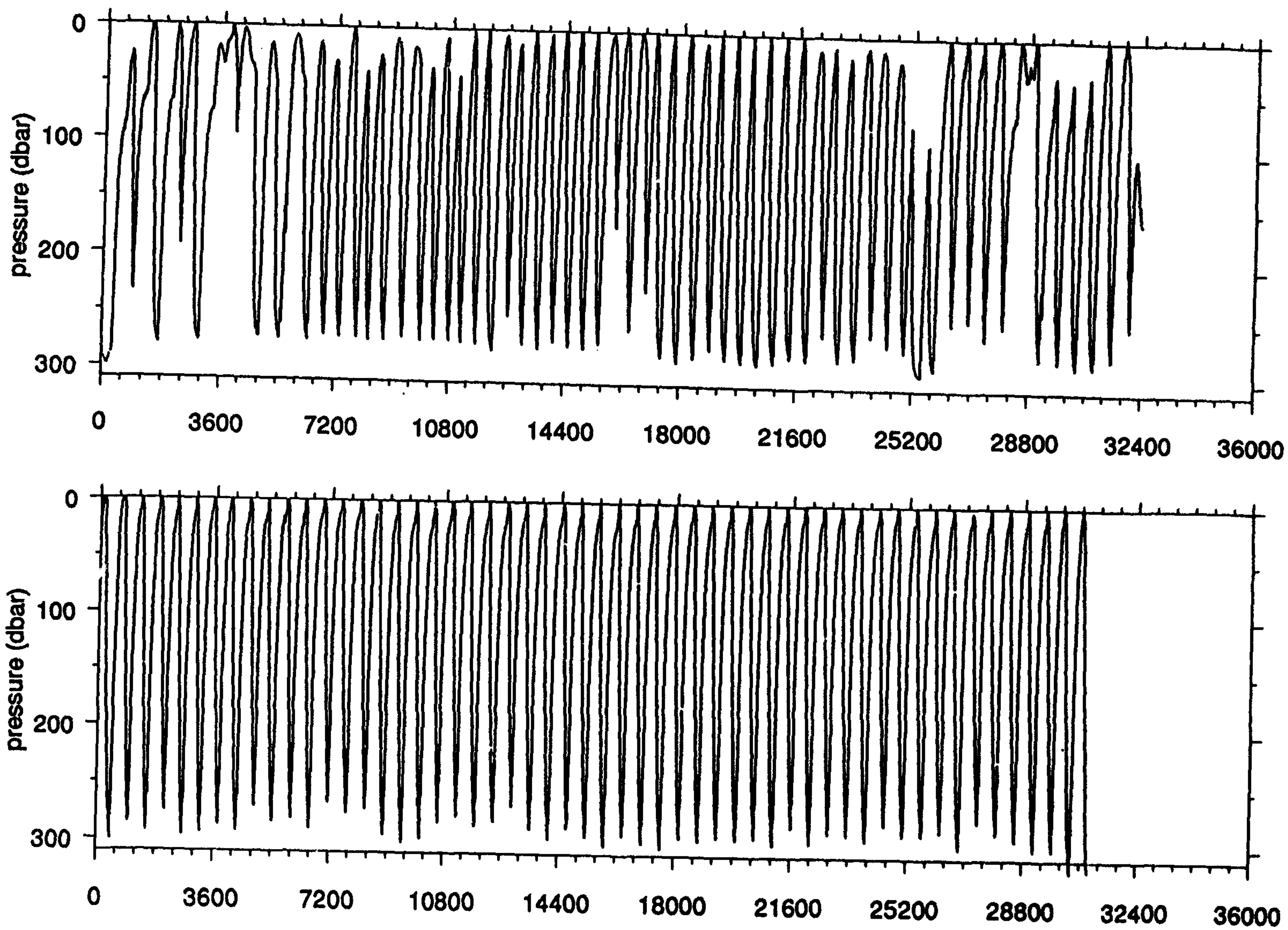

Figure 5. Examples of Seasoar trajectory (pressure *vs.* time in seconds) before and after changing the wing angle setting to from a maximum down-angle of 16° to a maximum down-angle of 17°. *Top*: the N2S section on 28 January during Tow 2. *Bottom*: the W2E section on 31 January during Tow 3.

Cruise Narrative, W9211C

Wecoma departed from Guam about 0000 UTC, 22 Jan 1993, and began a transit to 3°N, 156°E where we intended to begin a cross-equatorial Seasoar section. After arrival on 26 January, we made a pre-tow CTD cast (Station 1, Table 1) with an SBE 9/11 plus CTD with dual ducted temperature and conductivity sensors (Table 2). Seasoar was deployed for Tow 1 at about 0600 UTC, 26 Jan at 3°08'N, 156°07'E; the Seasoar vehicle (Figure 2) was equipped with an SBE 9/11*plus* CTD (SN 0256) with dual ducted temperature and conductivity sensors (Table 2; Figure 3). Tow 1 began normally, but in about 10 minutes the vehicle stopped responding to the control signal, and Seasoar was recovered on deck about 0845 UTC, 26 Jan. There was no evidence of a leak in the hydraulic unit, but it had definitely lost its power (after working successfully for more than 800 hours of consecutive towing in W9211A and W9211B). We then proceeded directly to the COARE Intensive Flux Array to begin sampling along the Standard Butterfly Pattern (Figure 1).

A new hydraulic unit (SN 011) was installed in the Seasoar vehicle, and the pushrods were adjusted to set the wing-angle so that the maximum up-angle was 23° and the maximum down-angle was 16° (Figure 4).

When we arrived at SBN, the northern apex of the Standard Butterfly Pattern, we made a pre-tow CTD cast to 500 m (Station 2, Table 1) and then deployed Seasoar at about 0845 UTC, 27 January. Tow 2 began southward toward SBS along the N2S line and continued along the Standard Butterfly in the usual direction (Table 3); for a 12-km portion of the line between SBE and SBN, the Seasoar was kept at depths below 30 m to avoid contamination from emptying the ship's tanks. The Seasoar vehicle was very difficult to control in the presence of strong vertical shear, so the resulting trajectories were quite irregular (e.g., Figure 5); we tentatively concluded that the 16° down-angle was too shallow. Preliminary temperature and salinity profiles and T-S diagrams showed there was a flow-rate problem through both T-C ducts from about the beginning of Tow 2, particularly during descent. Seasoar was recovered at SBS at about 0500 UTC, 29 January and we found that the outflow from the pumps was not connected to the tubes leading to the outlet ports through the nose of the vehicle (Figure 3); instead, the outflow from both sensor ducts was about 10 inches above the intake and into the interior of the Seasoar vehicle during Tow 2. CTD Station 3 (Table 1) was completed immediately after recovery.

After Tow 2, we changed the Seasoar wing angle setting to yield a maximum up-angle of 22° and a maximum down-angle of 17° (Figure 4) and reinstalled the CTD, checking the continuity of both sensor ducts with running

Table 3. Times (UTC) of standard waypoints during Tow 2 of W9211C. Positions of these waypoints are: SBN (1°14'S, 156°06'E); SBS (2°26'S, 156°06'E); SBW (1°50'S, 155°30'E); SBE (1°50'S, 156°42'E).

	Begin/End	SBN	SBS	SBW	SBE
27 January	0846	0917	1827		
28 January				0143	1207
28 January		1930			
29 January			0430		
29 January	0503				

Table 4. Times (UTC) of standard waypoints during Tow 3 of W9211C.

	Begin/End	SBN	SBS	SBW	SBE
29 January	0920			1646	
30 January					0225
30 January		0945	1926		
31 January				0238	1112
31 January		1827			
1 February			0358	1124	2015
2 February		0320	1221	1925	
2 February	2004				

Table 5. Times (UTC) of standard waypoints during Tow 4 of W9211C.

	Begin/End	SBN	SBS	SBW	SBE
3 February	1306			1410	2304
4 February		0604	1524	2230	
5 February					0719
5 February		1425			
6 February			0015	0747	1641
6 February	2315				

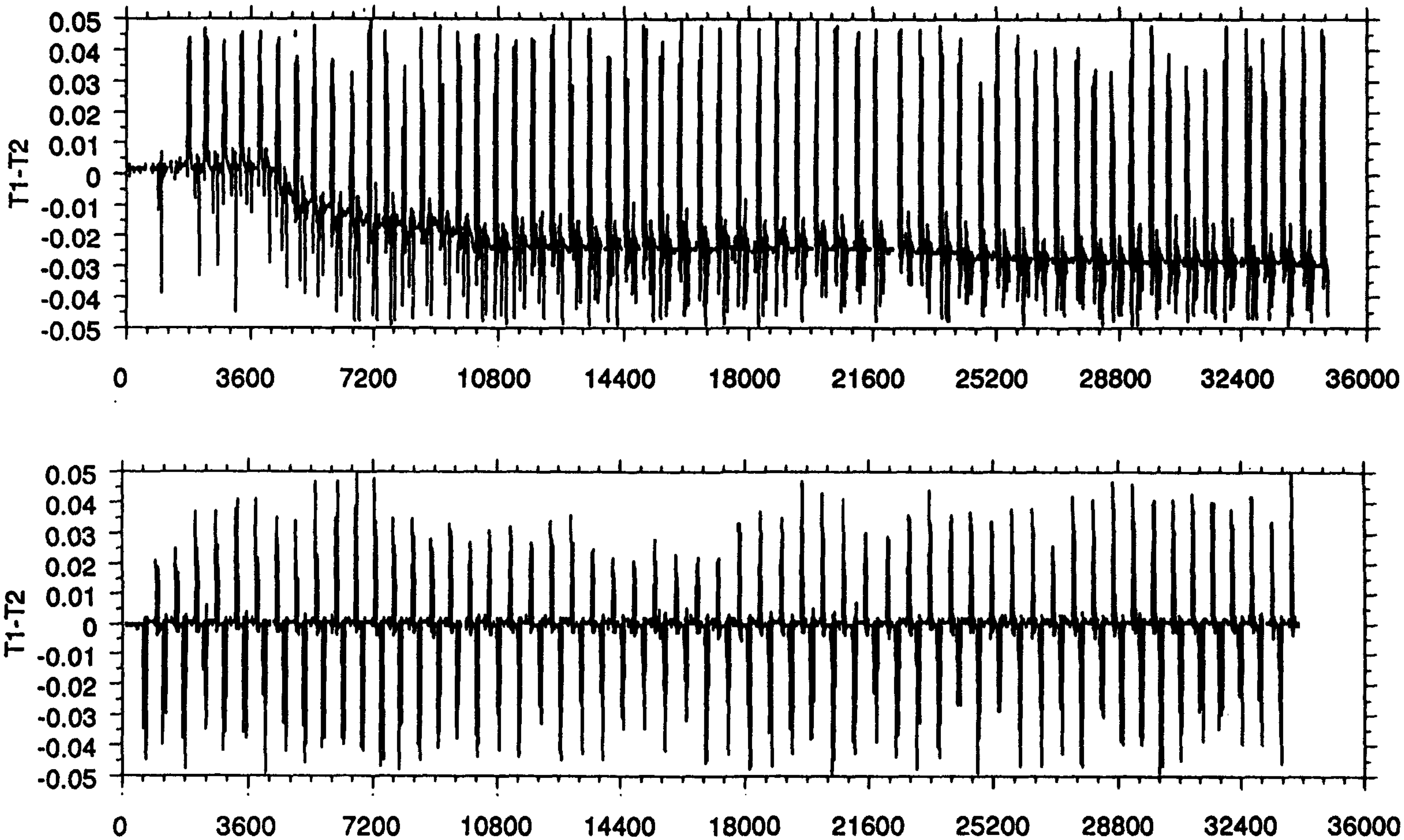

Figure 6. Time series of the preliminary temperature differences before and after changing both primary and secondary temperature sensors in Seasoar; high frequency fluctuations seem to be due to vehicle roll, i.e., to small differences in the depth of the two sensors. *Top*: the difference between sensors SN 1364 and 1366 during the W2E section on 29 January; sensor 1366 malfunctioned. *Bottom*: the difference between sensors SN 997 and 1384 during the W2E section on 11 February.

Table 6. Times (UTC) of standard waypoints during Tow 5 of W9211C.

	Begin/End	SBN	SBS	SBW	SBE
7 February	2058	2200			
8 February			0820	1524	
9 February					0114
9 February		0803	1824, 1921		
10 February				0200	1128
10 February		1819			
11 February			0452	1207	2135
12 February		0433	1456		
12 February	2036				

Table 7. Times (UTC) of standard waypoints during Tow 6 of W9211C.

	Begin/End	SBN	SBS	SBW	SBE
13 February	0551			0845	1856
14 February		0151	1139	1833	
15 February					0456
15 February		1137			
15 February	2047				

Table 8. Summary of Seasoar Tows, W9211C. Parameter values in the last column (for the T/C alignment offset, and for the amplitude and time constant of the thermal mass of the conductivity cell) were used for the preliminary (at-sea) data processing.

Tow No.	Start Time	Stop Time	Duration (hrs)	Parameters Measured	T/C Pair (and Parameter used for At-Sea Analysis
1	01/26/0605	01/26/0840	0	P, T1, C1, T2, C2	T2, C2 (3.25, 0.045, 8.0)
2	01/27/0846	01/29/0500	50	P, T1*, C1*, T2*, C2*	T2, C2 (3.25, 0.045, 8.0)
3	01/29/0920	02/02/2004	106	P, T1, C1, T2, C2	T2, C2 (3.25, 0.045, 8.0)
4	02/03/1306	02/06/2315	80	P, T1, C1, T2*, C2*	T1, C1 (2.00, 0.045, 5.0)
5	02/07/2059	02/12/2033	118	P, T1, C1, T2, C2	T2, C2 (2.00, 0.045, 5.0)
6	02/13/0551	02/15/2045	62	P, T1, C1, T2, C2	T2, C2 (2.00, 0.045, 9.0)

*Use data from ascending profiles only; outlet of T-C duct was into the interior of the Seasoar vehicle.

water. Tow 3 was deployed at about 0915 UTC, 29 January at 2°22'S, 156°02'E near SBS immediately after CTD Station 4. Tow 3 began northwestward toward SBW along the S2W line, and continued along the Standard Butterfly Pattern in the usual direction (Table 4). The Seasoar trajectory (Figure 5) was greatly improved over the previous tow, presumably because of the 1° change in the wing-angle setting. Preliminary T-S diagrams showed that data quality from both sensor pairs was also greatly improved. Preliminary time series of the temperature difference between T1 and T2 showed both drift and offsets larger than expected from SBE specifications (Figure 6). Tow 3 continued for more than 4 days (Table 4). Seasoar was recovered near SBW at about 2010 UTC, 2 February and CTD Station 5 (Table 1) was completed immediately after recovery.

After Tow 3, we replaced both primary and secondary temperature sensors with sensors without a reed-switch assembly (SN 997 and 1384) to reduce the likelihood of damage from vibration, and reterminated the tow cable. Wecoma ran at full speed for a few hours to clear the exhaust system.

Seasoar was deployed near SBW at about 1300 UTC, 3 February immediately after CTD Station 6, and Tow 4 proceeded along the Standard Butterfly pattern in the usual direction (Table 5). Preliminary salinity data from the secondary sensor pair were very noisy during ascending profiles, and we suspected a problem with the sensor duct. Preliminary time series of the difference between the two temperature sensors showed no evidence of drift or offset (Figure 6). The temperature and conductivity data became intermittent during the E2N section of 6 February, so the vehicle was recovered near SBN at about 2315, 6 Feb and CTD Station 7 was made soon afterward. We found that the outlet tube for the secondary sensors had become detached from the nose, so the actual outlet from these sensors was inside the vehicle.

After Tow 4, we reterminated the Seasoar cable again, using a modified wire grip instead of the standard tapered plastic cow-tail to reduce cable flexing. We also repaired the secondary outlet duct, so that this outlet was once again directly through the nose of the Seasoar vehicle. Seasoar was deployed near SBN at about 2100, 7 February, immediately after CTD Station 8 (Table 1). Tow 5 began southward toward SBS and continued along the Standard Butterfly in the usual direction for almost five days (Table 6), when it was terminated at about 2° on the S2W line to allow the ship to make a high-speed run to clear the exhaust system; CTD Station 9 was made immediately after recovery. The Seasoar vehicle, instrument and termination were apparently in excellent condition. During CTD Station 10, as we were preparing to deploy Seasoar for Tow 6, we found a broken strand in the Seasoar cable adjacent to the loop attached for

crane handling. We therefore cut the cable above this point and reterminated the cable.

Seasoar was deployed for Tow 6 at about 0545 UTC, 13 February at 1°59'S, 155°43'E on the S2W line, immediately after CTD Station 11. Tow 6 began northwestward toward SBW and continued along the Standard Butterfly in the usual direction (Table 7) until 1137 UTC, 15 February, when we turned northward toward the equator. Seasoar was recovered just south of the equator at about 2045 UTC, 15 February, and CTD Station 12 was completed immediately afterward. We then ceased operations in the COARE IFA, and Wecoma proceeded to Pohnpei.

In all, we completed six Seasoar tows during W9211C (Table 8), for a total towing time of 416 hours. The overall Seasoar sampling included 12 occupations each of the N2S and W2E lines (Table 9) and the S2W and E2N lines (Table 10).

Wecoma arrived in Pohnpei at about 2300 UTC, 17 Feb, to disembark some personnel and departed there at about 0600 UTC, 18 Feb for the transit to Guam. En route to Guam, we conducted an 8-hour test of Seasoar flight characteristics with an optical plankton counter attached to the vehicle. Wecoma arrived in Guam at 0400 UTC, 22 Feb.

Underway measurements were made continuously through most of the cruise. These include: Acoustic Doppler Current Profile measurements of water velocity relative to the ship and accompanying GPS position data (contact Eric Firing et al., Univ. of Hawaii); temperature and salinity of water at 5 m depth and 2 m depth (contact Clayton Paulson, Oregon State Univ.); near-surface salinity of water pumped from a buoyant hose (contact Gary Lagerloef, SAIC); microwave radiometer estimates of surface salinity (contact Gary Lagerloef, SAIC); and a broad spectrum of meteorological observations (contact Clayton Paulson, OSU) including sonic inertial dissipation (contact Jim Edson, WHOI).

Members of the scientific party included Marc Willis, Tim Holt (both Wecoma Marine Technicians), Adriana Huyer, Robert L. Smith, Fred Bahr, Pip Courbois, Jane Fleischbein (all from Oregon State University), Eric Firing, Fred Bingham, Tung Le, Dail Rowe, and Joanna Muench, (all from University of Hawaii), Clay Wilson (SAIC) and Jonas Aleksa (University of Massachusetts). Additional persons on the Pohnpei-Guam transit were Mike Hill (Oregon State University), Meng Zhou, and Walter Nordhausen (both from Scripps Institution of Oceanography).

Table 9. Times (UTC) of meridional and zonal sections of the Standard Butterfly pattern. All N2S sections were southward along 156°06'E from SBN (1°14'S) to SBS (2°26'S), and all W2E sections were eastward along 1°50'S from SBW (155°30'E) to SBE (156°42'E). Number in parentheses indicates intake of preferred sensor T/C sensor pair was on port (1) or starboard (0) side of Seasoar)

N2S (SBN to SBS) along 156°06'E	W2E (SBW to SBE) along 1°50'S
0917, 27 Jan to 1827, 27 Jan* (0)	0143, 28 Jan to 1207, 28 Jan* (0)
1930, 28 Jan to 0430, 29 Jan*(0)	1646, 29 Jan to 0225, 30 Jan** (0)
0945, 30 Jan to 1926, 30 Jan (0)	0238 to 1112, 31 Jan (0)
1827, 31 Jan to 0358, 1 Feb (0)	1124 to 2015, 1 Feb (0)
0320, 2 Feb to 1221, 2 Feb (0)	1410 to 2304, 3 Feb (0)
0604, 4 Feb to 1524, 4 Feb (0)	2230, 4 Feb to 0719, 5 Feb (0)
1425, 5 Feb to 0015, 6 Feb (0)	0747 to 1641, 6 Feb (0)
2200, 7 Feb to 0820, 8 Feb (1)	1524, 8 Feb to 0114, 9 Feb (1)
0803 to 1824, 9 Feb[1] (1)	0200 to 1128, 10 Feb (1)
1819, 10 Feb to 0452, 11 Feb (1)	1207 to 2135, 11 Feb (1)
0433 to 1456, 12 Feb (1)	0845 to 1856, 13 Feb (1)
0151 to 1139, 14 Feb (1)	1833, 14 Feb to 0456, 15 Feb (1)

* Data from ascending profiles only.
** Includes a 6 second data gap from 20:52:25 through 20:53:30 UTC, 29 January.
[1] Section extends past SBS to 2°29'S.

Table 10. Times (UTC) of diagonal sections of the Standard Butterfly pattern: S2W between SBS (2°26'S, 156°06'E) and SBW (1°50'S, 155°30'E); and E2N between SBE (1°50'S, 156°42'E) and SBN (1°14'S, 156°06'E). During most E2N sections Seasoar was kept at maximum depth for about 12 km.

S2W (SBS to SBW)	E2N (SBE to SBN)
1827, 27 Jan to 0142, 28 Jan* (0)	1207, 28 Jan to 1930, 28 Jan* (0)
1035, 29 Jan to 1646, 29 Jan (0)	0225 to 0945, 30 Jan (0)
1926, 30 Jan to 0238, 31 Jan (0)	1112 to 1827, 31 Jan (0)
0358, 1 Feb to 1124, 1 Feb (0)	2015, 1 Feb to 0320, 2 Feb (0)
1221, 2 Feb to 1925, 2 Feb (0)	2304, 3 Feb to 0604, 4 Feb (0)
1524 to 2230, 4 Feb (partial) (0)	0719 to 1425, 5 Feb (0)
0015 to 0747, 6 Feb (0)	1641 to 2315, 6 Feb (partial)** (0)
0820 to 1524, 8 Feb (1)	0114 to 0803, 9 Feb (1)
1824, 9 Feb to 0200, 10 Feb (1)	1128 to 1819, 10 Feb (1)
0452 to 1207, 11 Feb (1)	2135, 11 Feb to 0433, 12 Feb (1)
1456 to 2036, 12 Feb (partial) (1)	
0641 to 0845, 13 Feb (partial) (1)	1856, 13 Feb to 0151, 14 Feb (1)
1139 to 1833, 14 Feb (1)	0456 to 1137, 15 Feb (1)

*Data from ascending profiles only.
** Includes numberous short gaps after 22:06:27 UTC, 6 February.

CTD Data Acquisition, Calibration and Data Processing

All CTD/rosette casts were made with an SBE 9/11-plus CTD system equipped with dual ducted temperature and conductivity sensors (Table 2). CTD casts were made primarily to monitor the calibration of the Seasoar data, and were therefore made before and after each Seasoar tow, with as little delay as possible. Maximum sampling depth was about 500 m. Raw 24 Hz CTD data were acquired on an IBM compatible PC using the SEASAVE module of SEASOFT version 4.015 (Anon., 1992); temperature and conductivity data were recorded from both pumped sensor ducts. At each station a few salinity samples were collected for *in situ* calibration of the conductivity sensors; CTD values at the sample depth (calculated from the most recent manufacturer's pre-cruise calibration) were recorded both by pressing the F5 key at the time of rosette firing and manually on the station log sheets. Samples were analyzed on a Guildline Autosal salinometer that was standardized with IAPSO Standard Water P-119 at the beginning and end of each batch of about 36 samples. Sample salinity values were in essential agreement with the calculated CTD salinity values from both sensor pairs (average $\Delta S1=0.002$, with standard deviation of 0.004, 36 samples: average $\Delta S2=0.002$, with standard deviation of 0.005, 33 samples), and hence no conductivity correction was applied.

CTD data were processed on an IBM-compatible PC using applicable SEASOFT modules. Since there was no significant difference between the data from the two sensor pairs, we fully processed data from the primary sensors only. The DATCNV module of SEASOFT was used with the pre-cruise calibration constants to calculate 24 Hz values of pressure, temperature and conductivity from the raw frequencies. When necessary, the output data file was edited to remove any spikes and any values inadvertently recorded before the pressure minimum at the beginning of the cast. The CELLTM module was used to correct for the thermal mass of the conductivity cell, assumed to have a thermal anomaly amplitude of 0.03 and a time constant of 9 seconds. Ascending portions of the 24-Hz data file were removed by LOOPEDIT with the minimum velocity set to 0.0 m/s. The remaining data were averaged to 1 dbar values using BINAVG. The final processed data files consist of 1 dbar values of pressure, temperature and conductivity. These processed data files were transferred to a SUN computer where we used standard algorithms (Fofonoff and Millard, 1983) to calculate salinity, potential temperature, density anomaly (sigma-theta), specific volume anomaly, and geopotential anomaly (dynamic height).

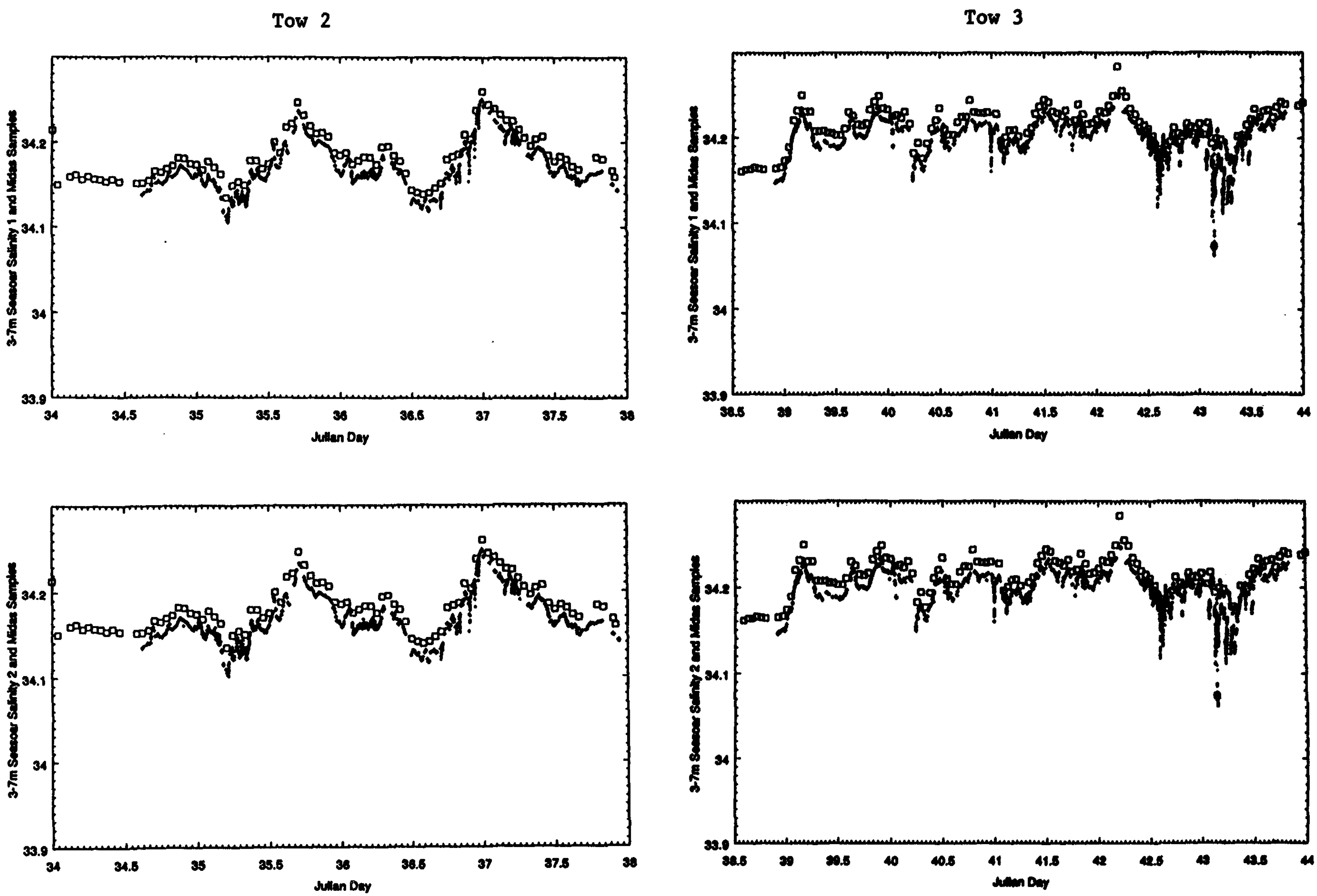

Figure 7(a). Time series of hourly salinity samples from the ship's intake at 5 m (squares), and of preliminary near-surface (3-7.99 m) Seasoar salinity data (dots) from both primary (upper panel) and secondary sensors (lower panel), for each Seasoar tow of W9211C: Tow 2 (left) and Tow 3 (right) of W9211C.

Seasoar Data Acquisition and Preliminary Processing

Raw 24 Hz CTD data from the Seasoar vehicle and GPS position and time data were acquired by an IBM compatible PC, which also set flags to indicate missing GPS data and to mark the collection of a salinity sample. The raw data were simultaneously recorded on optical disk by PC and on a Sun Sparc workstation. The PC displayed time series of subsampled temperature (both sensors), conductivity (both sensors) and pressure in real time; it also displayed accumulated temperature data for 6-8 hours as a vertical section (color raster). One-second averages of ship's position, CTD temperature (both sensors), conductivity (both sensors), salinity (both sensor pairs), and pressure were calculated on the Sparc workstation, using the most recent manufacturer's calibration (Table 2). For each tow, the preliminary salinity for each sensor pair was calculated using a fixed offset between temperature and salinity, and a fixed value for the amplitude and time constant of the thermal mass of the conductivity cell, but these parameters were changed from one tow to another (Table 8). Time-series and vertical profile plots of the one-second data were made at the end of each hour. The 1-second preliminary data were used to calculate the average temperature and salinity data in bins extending 3 km in the horizontal and 2 dbar in the vertical, and these gridded values were used to plot vertical sections for each leg of the Standard Butterfly pattern.

Seasoar Conductivity Calibration

Salinity samples were collected once per hour from a throughflow system in Wecoma's wetlab from 0000 UTC, 27 January until 2000 UTC, 15 February 1993. This system pumps water from the seachest at a depth of 5 m in the ship's hull, through a tank containing SBE temperature and conductivity sensors; samples are drawn from a point just beyond this tank. The 120 ml glass sample bottles were rinsed three times before filling, and closed with screw-on plastic caps with conical polyethylene liners. Samples were further sealed by wrapping parafilm around the base of the cap. Samples were analyzed at sea on an Autosal salinometer, usually within 2-3 days after collection; the salinometer was standardized with IAPSO Standard Water P-119 at the beginning and end of each batch of about 24 samples. Time series of these hourly salinity samples and time series of the preliminary Seasoar data from the 3-7 m depth range (Figure 7) show very similar variations, especially during Tows 4-6.

For a quantitative comparison between the salinity samples and the Seasoar data, we selected Seasoar values that were both within 7 minutes of the time of the salinity sample and within a depth range of 3.0 to 5.5 m. For each salinity sample, we calculated a bottle conductivity using the measured salinity and the temperature from each Seasoar sensor duct, and then compared this sample conductivity to the directly

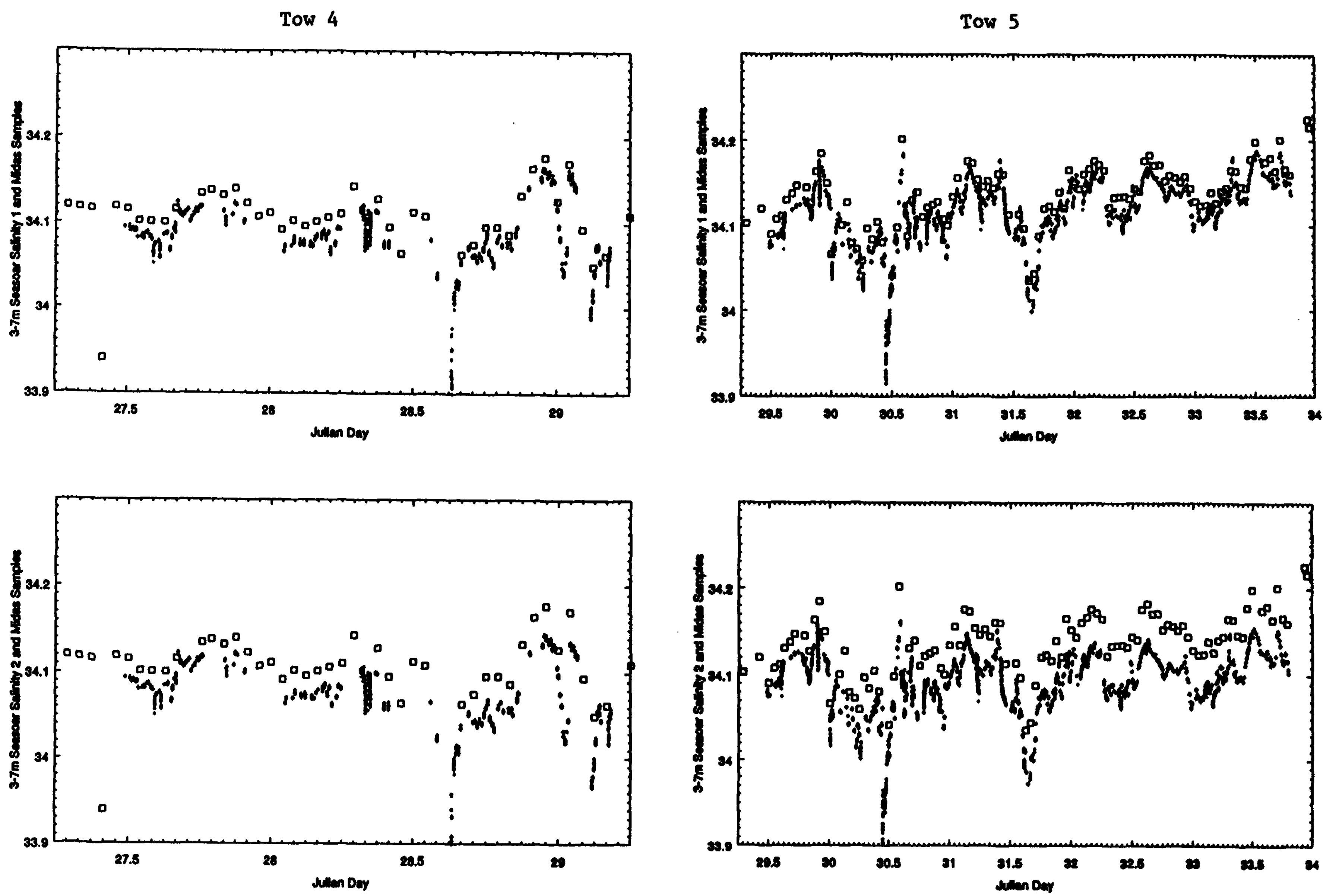

Figure 7(b). Time series of hourly salinity samples from the ship's intake at 5 m (squares), and of preliminary near-surface (3-7.99 m) Seasoar salinity data (dots) from both primary (upper panel) and secondary sensors (lower panel), during Tow 4 (left) and Tow 5 (right) of W9211C.

Tow 6

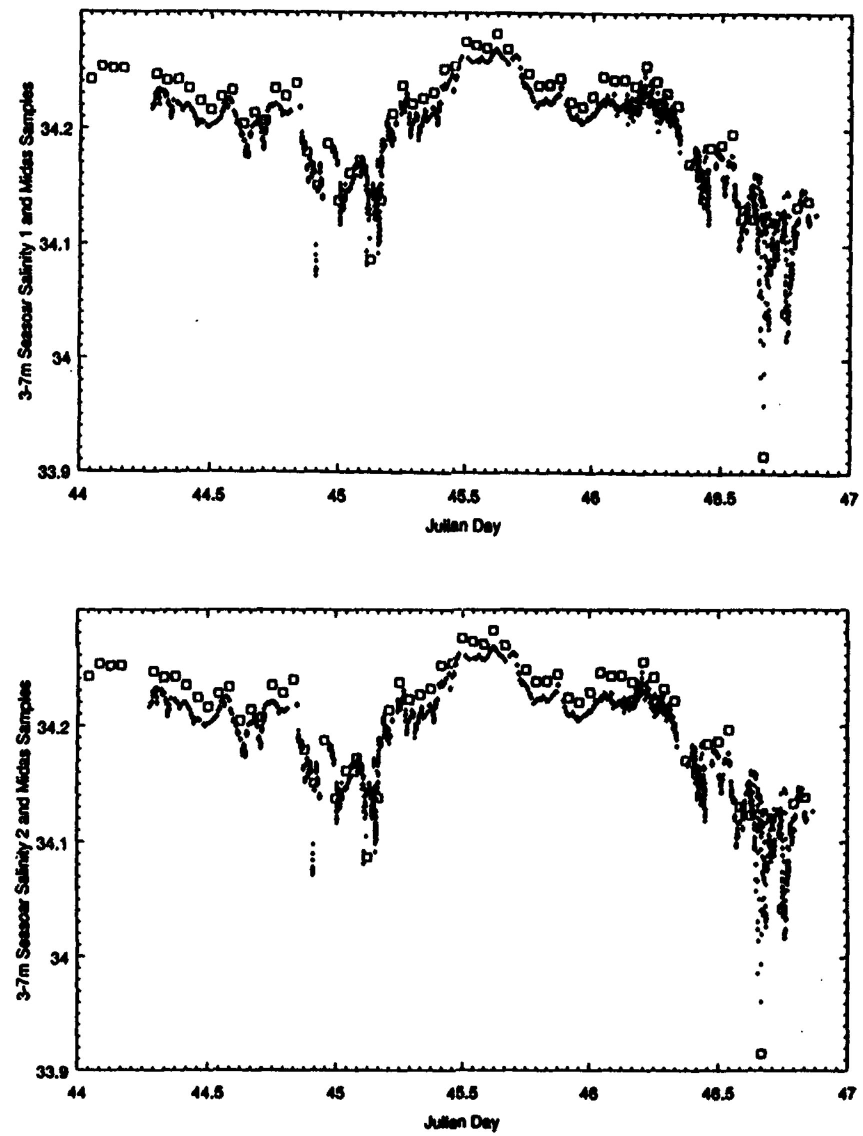

Figure 7(c): Time series of hourly salinity samples from the ship's intake at 5 m (squares), and of preliminary near-surface (3-7.99 m) Seasoar salinity data (dots) from both primary (upper panel) and secondary sensors (lower panel), during Tow 6 of W9211C.

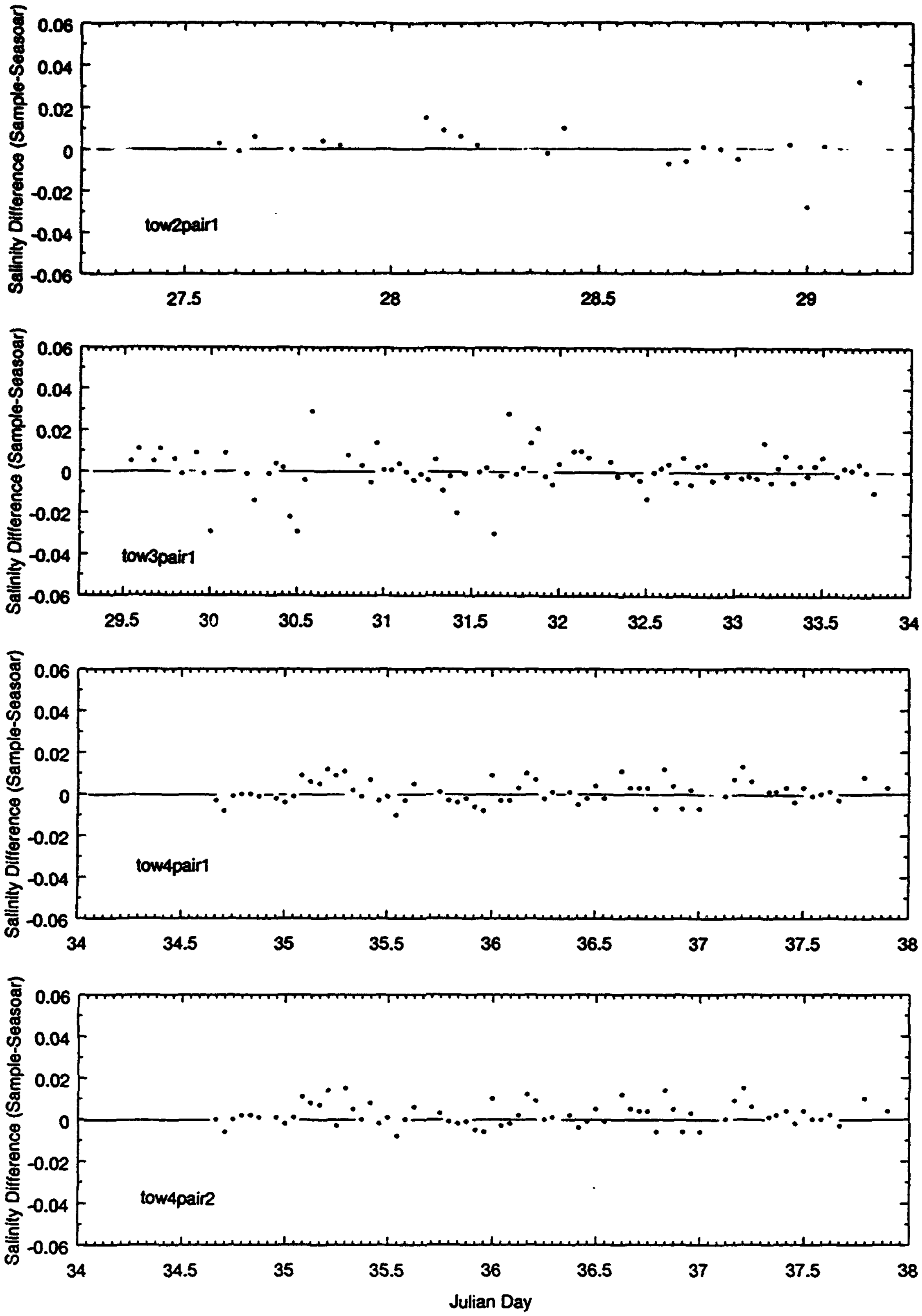

Figure 8 (a). Time series of salinity differences between the 5-m samples and the matching corrected Seasoar data, for the primary T/C sensor pair during Tows 2 and 3, and for both primary and secondary sensors during Tow 4 of W9211C.

measured conductivity from the same sensor duct; a very few pairs with very large differences (only 5 out of a total of 329) were eliminated from the comparison. Assuming, as usual, that the measured conductivity should be corrected by a multiplier alone, we calculated the slope (m) of the zero-intercept regression line between the measured conductivity and the sample conductivity separately for each sensor pair and for each Seasoar tow.

Between Tows 2 and 3, we found no significant difference in the multiplier for the primary sensor pair, and therefore we pooled the data, and used the same correction factor (k) for both tows (Table 11). Since the secondary temperature sensor malfunctioned during Tows 2 and 3, we used the primary temperature data to determine the multiplier for secondary conductivity for these tows. Both primary and secondary sensors were replaced after Tow 3.

Between Tows 4, 5 and 6, we found no significant difference in the multiplier (m) for either the primary or secondary conductivity data, and therefore we adopted the values determined from the pooled data as the correction factors (Table 11).

Applying these multipliers to the Seasoar conductivity data before recalculating salinity allows us to compare the corrected Seasoar salinity values from both primary and secondary sensor ducts to the sample salinity (Figure 8, Table 11). The time series of the differences (Figure 8) show reasonable agreement between sample and near-surface Seasoar data for the primary sensor pairs during Tows 2 and 3, and for both sensor pairs during Tows 4, 5 and 6. In general, largest sample-Seasoar differences occur when the surface layer is stratified, so the standard deviations of the salinity differences (Table 11) primarily reflect sampling errors rather than instrumental noise.

Table 11. Conductivity multipliers (m1 and m2) for primary and secondary sensors, determined (separately for each tow) from comparison of near-surface Seasoar data with 5-m intake samples, and the conductivity correction factors (k1 and k2) adopted for reprocessing the Seasoar conductivity data. Also shown are the average and standard deviations of the salinity differences between the sample values and the corrected Seasoar data.

						Average		Std. Dev.	
Tow	N	m1	m2	k1	k2	S1	S2	S1	S2
1	0	–	–	1.000433	1.000449	–	–	–	–
2	21	1.000470	–	1.000433	1.000449	0.001	–	0.007	–
3	84	1.000424	–	1.000433	1.000449	0.000	–	0.009	–
4	67	1.000388	1.000460	1.000368	1.000418	0.001	0.002	0.004	0.004
5	100	1.000354	1.000396	1.000368	1.000418	-0.001	-0.001	0.007	0.008
6	52	1.000396	1.000420	1.000368	1.000418	0.002	0.000	0.012	0.012

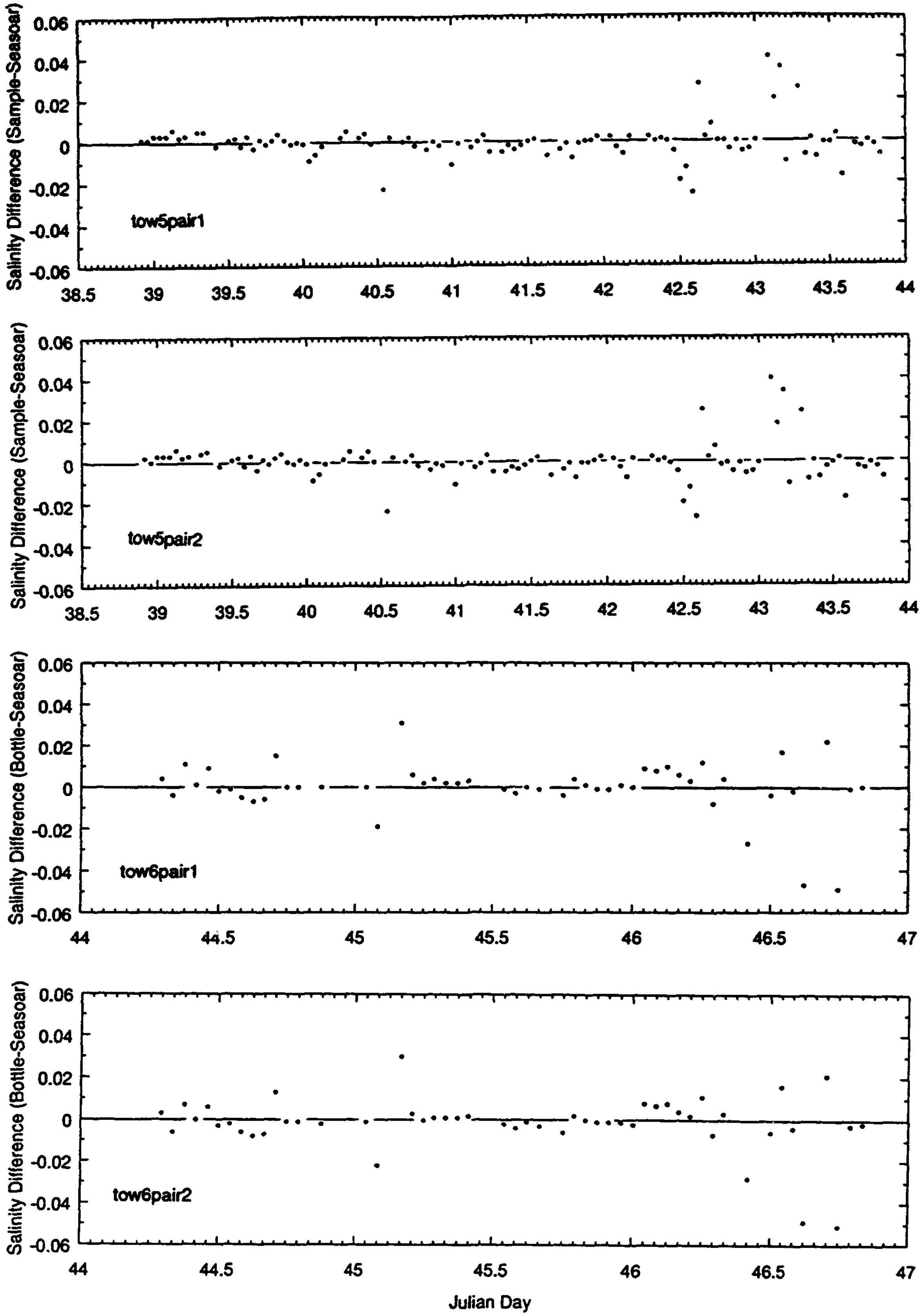

Figure 8 (b). Time series of salinity differences between the 5-m samples and the matching corrected Seasoar data, for both primary and secondary sensor pairs during Tows 5 and 6 of W9211C.

Post-processing of Seasoar Data

Background Salinity data derived from SeaBird ducted temperature and conductivity sensors are subject to errors from three separate sources (Larson, 1992): (1) poor alignment of the 24 Hz temperature and conductivity data, (2) poor compensation for the transfer of heat between the mantle of the conductivity cell and the water flowing through it, and (3) mismatch of the effective time constants of the temperature and conductivity measurements. These sources of error are minimized in a normal SeaBird CTD, by pumping the water through the ducted pair at a fixed rate, by software algorithms for changing the T/C alignment and the thermal mass parameters, and by matching the thermistor to the effective time constant of the conductivity measurement through the fixed-length duct. With sensors mounted inside a towed Seasoar vehicle, these error sources need to considered anew.

While at sea, we noticed that there was often a significant difference in data quality between ascending and descending profiles, with salinity data from descending profiles generally noisier than salinity data from ascending profiles; descending profiles frequently showed a large and variable positive salinity bias (e.g. Figure 9). These systematic up/down differences were observed in data from both sensor pairs, though sometimes more pronounced in one of the sensor pairs. We therefore suspected that there might be variations in the flow-rate of water through the pumped T/C sensor ducts, leading to variations in the optimum alignment offset between the 24-Hz temperature and conductivity data.

To check this hypothesis, we applied the general procedures outlined by Nordeen Larson (1992) to a segment of raw data from the hour beginning at 0000 UTC, 9 February. We first reprocessed the data from both sensor pairs without applying any T/C offset, retaining 24-Hz output; data from the first ascending profile (about 0001 to 0006 UTC) and the first descending profile (0006 to 0010 UTC) were read into separate files. These served as input to a program which realigns the temperature and conductivity data from both sensor pairs by a specified offset and recalculates salinity; for each scan it also determines a "median salinity", S_m, using a centered nine-point median filter, and a "spike salinity", S', as the anomaly from the median salinity. The time integral of this spike salinity, normalized by the sign of the temperature gradient,

$$ISS = \Sigma\,(S'_n/\mathrm{sgn}(T_{n+1}-T_{n-1})),$$

changes sign at the optimum offset value (Larson, 1992). Calculations were repeated for a range of offsets, and spike salinity profiles were plotted for each (e.g., Figure 10). For these profiles, we found that the optimum alignment offset, ξ, during

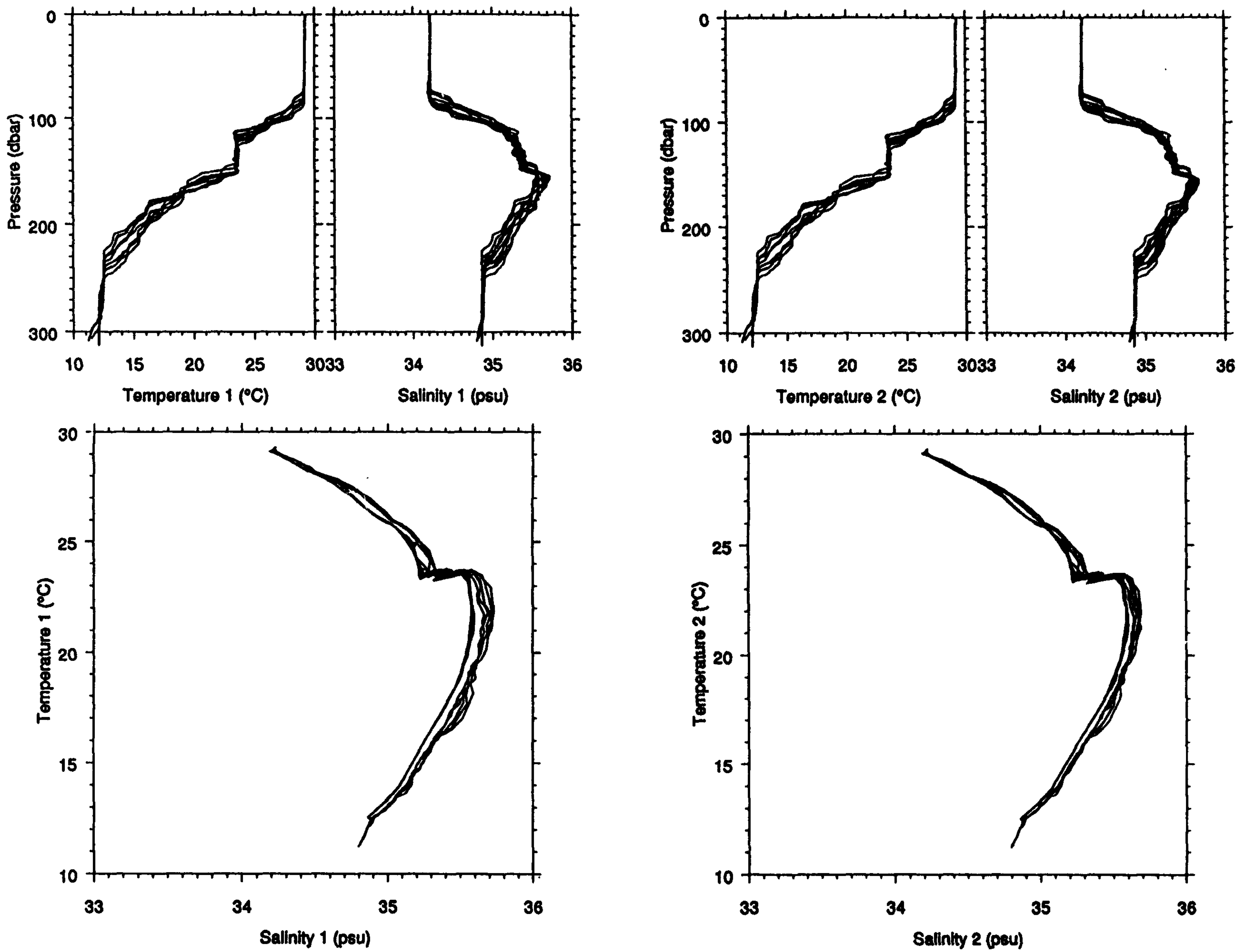

Figure 9. Preliminary profiles and T-S diagrams for both Seasoar T/C sensor pairs, for the hour beginning 0000 UTC on 9 February 1993. Data were processed with constant values of the T/C offset ($\xi_1 = 0.0$ and $\xi_2 = 2.0$) and thermal mass parameters ($\alpha = 0.045$ and $\tau = 5$ sec). For both sensor pairs, splitting of the T-S characteristics into two groups reflects systematic differences between ascending and descending profiles.

ascent was essentially the same as those for ducted sensors in a normal profiling SBE9/11 plus CTD, i.e. 0.0 scans for primary sensors and 1.75 scans for secondary sensors. (The SBE 11/plus deck unit previously applies a T/C alignment offset of 1.75 scans to data from primary sensors but not secondary sensors). Optimum values of the offset during descent were larger: 1.75 scans for primary sensors, and 2.75 scans for secondary sensors (Figures 10, 11).

We independently calculated lagged correlation coefficients between the temperature and conductivity data from each sensor pair, using first differencing to remove low frequency trends in both, and obtained the same results, and found that the lag of maximum correlation was in essential agreement with the alignment offset determined by Larson's spike salinity method. Alternating between two values of the alignment offset (one for descent, one for ascent) significantly improved the processed salinity data, but systematic up/down differences remained during portions of some Seasoar tows (e.g. Figure 12).

Further study of the 24-Hz Seasoar CTD data has shown that the optimum T/C alignment offset, ξ, varies on several different time scales: within each undulation, from section to section, gradually over the length of a tow, and from one tow to another (e.g., Figure 13). In most cases, the optimum alignment offset during ascent is near the default values of 0.0 scans for T1/C1 and 1.75 scans for T2/C2, while the optimum offset during descent is longer. We attribute these variations in optimum offset to reductions in the rate of pumped flow through the sensors, and believe these variations in flow rate are the result of dynamic pressure differences, partly between the inside and outside of the vehicle, and partly along the exterior of the vehicle nose (though inlet and outlet ports are separated by only a few centimeters). Possible sources of such pressure gradients include high rates of ascent and descent (sometimes >3 m/s, superimposed on a horizontal tow speed of 4 m/s), and local small perturbations of the flow field around the vehicle, associated perhaps with a persistent roll angle or strong cross-currents. Whatever their source, the variations in offset alignment are a major source of potential error in calculating salinity, and must be taken into account in reprocessing the data. After some trial and error, we chose to determine the optimum lag in three depth ranges (excluding the surface mixed layer) for each ascending and descending profile; calculating lags for successive 10-second segments proved to be less satisfactory in minimizing salinity noise and bias.

Still further study of the preliminary Seasoar data showed that systematic up/down salinity differences were particularly strong near sharp thermoclines, even though we had attempted to correct for the thermal mass of the conductivity cell (Lueck, 1990), using constant values for the time constant (τ) and amplitude (α) parameters in the recursive algorithm provided by SeaBird:

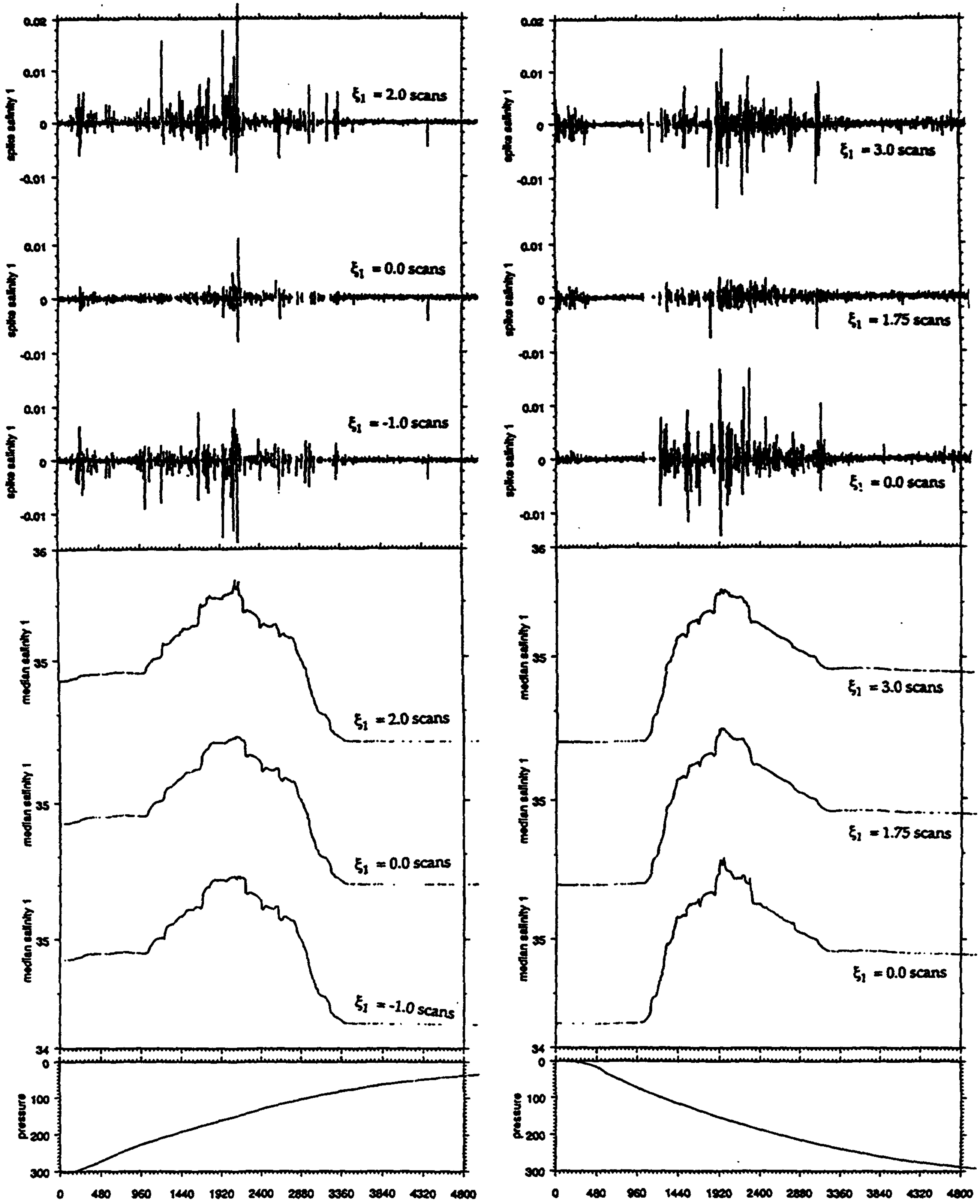

Figure 10. Time-series of 24-Hz "median salinity" and "spike salinity" from ascending (left) and descending (right) segments of Seasoar data between 0001 and 0010 UTC, 9 February, calculated for three different values of T/C alignment offsets ξ_1. The "median salinity" is the median of 9 scans, and the "spike salinity" is the anomaly from this median.

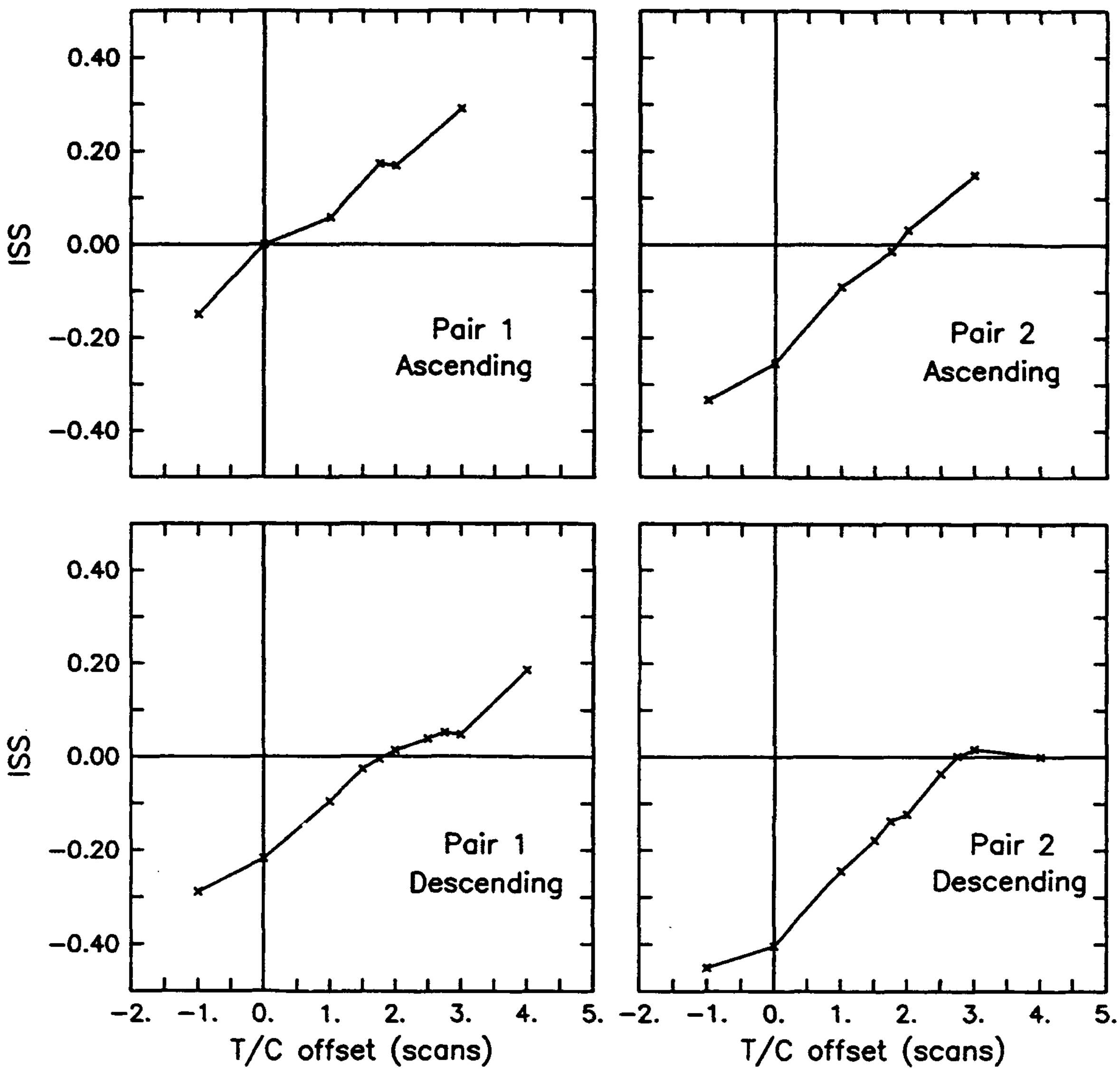

Figure 11. Values of the integral of spike salinity, ISS, for ascending and descending segments of data from both T/C sensor pairs, during 0001 and 0010 UTC, 9 February 1993; note that the value of the optimum offset (at ISS = 0) is larger during descent.

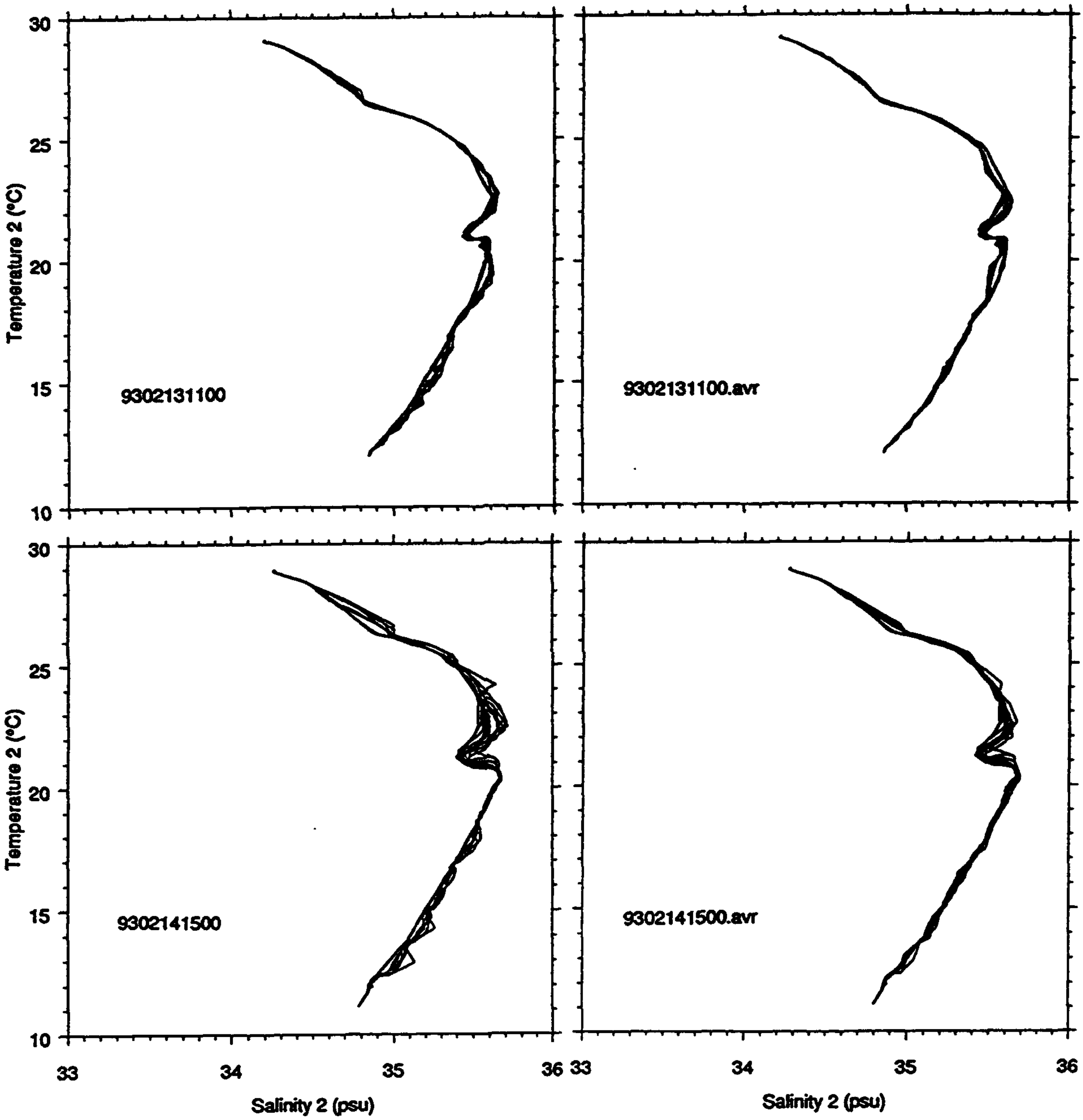

Figure 12. T-S characteristics for Seasoar data from two different hours, processed by two different methods: with constant values of the T/C alignment offset (left, $\xi_2 = 2.0$ scans), and with alternating values of the offset (right; $\xi_2 = 2.5$ scans during ascent and $\xi_2 = 5.0$ scans during descent). In both methods, we used constant values of the thermal mass parameters ($\alpha = 0.045$ and $\tau = 9$ sec).

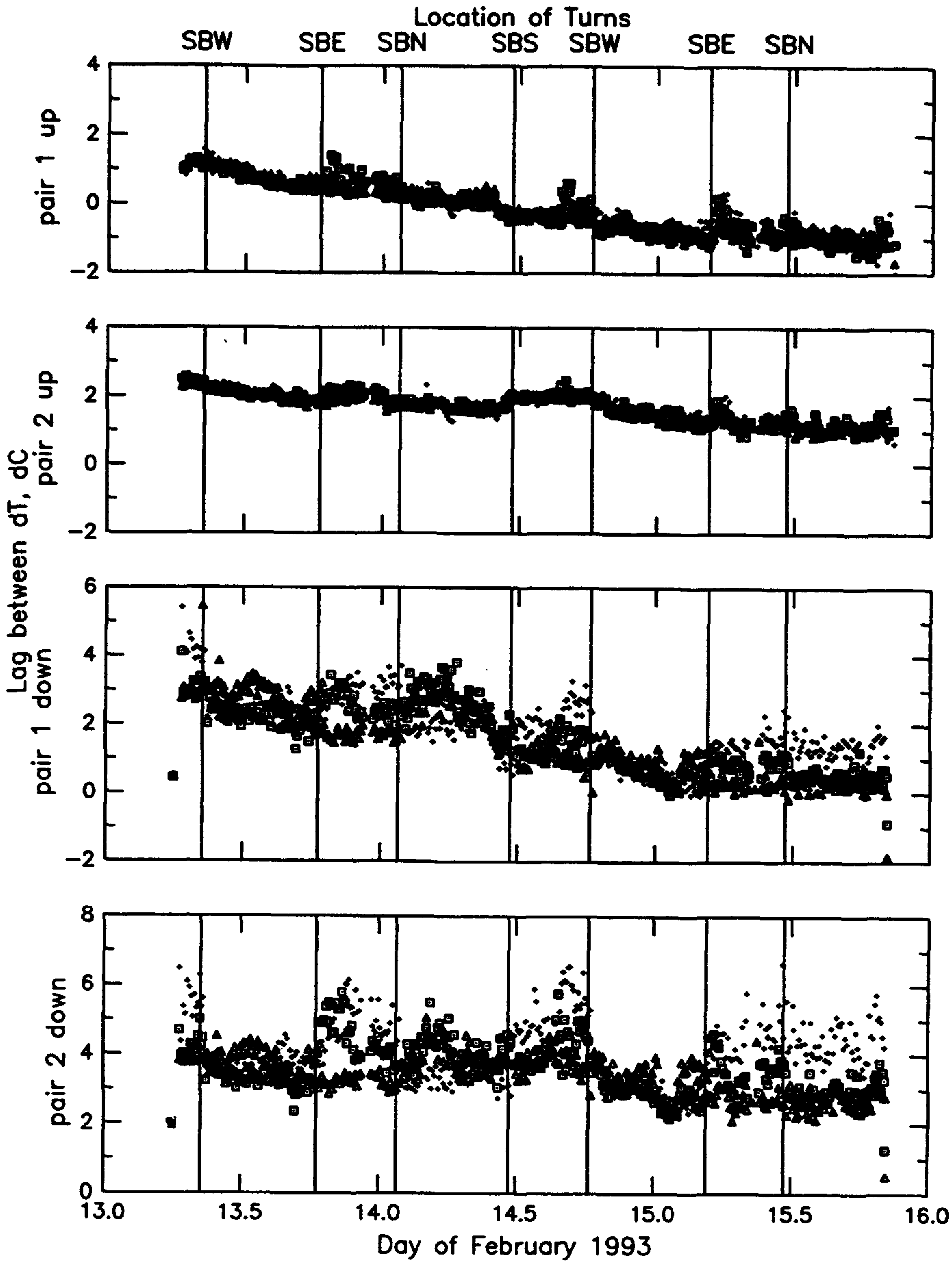

Figure 13. Time series of the lag at maximum cross-correlation between 24-Hz temperature and conductivity data (detrended by first-differencing), for both primary and secondary sensor pairs during Seasoar Tow 6. Correlations were calculated for three different layers (50-120 dbar, plus signs; 120-180 dbar, squares; 180-240 dbar, triangles), and separately for ascending and descending profiles; times of turns in the ship's track are indicated by vertical lines.

dt = temperature - previous temperature
ctm = - *b* * previous *ctm* + *a* * *dcdt* * *dt*
corrected conductivity = conductivity + *ctm*

where $a = 2\alpha / (0.0417\beta + 2)$, $dcdt = 0.1 + 0.0006$ (temperature - 20), $\beta = 1/\tau$ and $b = 1 - 2a/\alpha$. Constant values of α and τ had been chosen by two different methods: by comparing CTD casts with Seasoar deployment and recovery profiles, and by minimizing differences between ascending and descending salinity data near the top of the thermocline for some data segments with exceptionally steep gradients at the bottom of the surface mixed layer; both methods indicated the best constant values were $\alpha = 0.04$ for the thermal anomaly amplitude and $\tau = 10$ sec for the time constant. The association of residual salinity bias with sharp thermoclines suggested that variations in flow rate through the ducted sensors effectively altered the rate of heat transferred from the walls of the conductivity cell. Experimenting with different values of α indicated that larger values of α are appropriate for larger values of the alignment offset (Figure 14).

Finally, we considered the effect of elongating the intake duct (from about 1 cm on a standard SeaBird T/C ducted pair to about 5 cm) by adding Tygon tubing between the sensor duct and inlet in the Seasoar nose. In principle, elongating the intake could slow the response time of the conductivity measurement through turbulent mixing within the duct (Nordeen Larson, personal communication). We compared conductivity spectra from conventional CTD casts with those from the Seasoar deployment and recovery profiles, and found no significant difference: both were similar to the temperature spectra. We conclude that any change in sensor time constant due to intake elongation is negligible, at least with the present choice of tubing.

Procedures The first step in reprocessing is to incorporate temperature and conductivity corrections determined from in-situ calibration or post-cruise calibration in a new configuration file for each tow. Except for temperature sensor #1369, which clearly malfunctioned during the cruise, the post-cruise temperature calibrations of the Seasoar sensors showed little or no drift from the pre-cruise calibrations, so no temperature corrections were applied. The conductivity correction factors determined from the *in situ* calibration data (Table 11) were incorporated in the configuration files for each tow.

The next step is to compute lagged correlations between temperature and conductivity for each sensor pair, separately for ascending and descending profiles, and separately for three depth ranges: 50 to 120 dbar, 120 to 180 dbar, and 180 to 240 dbar, provided the segment contains at least 72 scans. Cross-correlations are calculated after detrending both temperature and conductivity by first-differencing

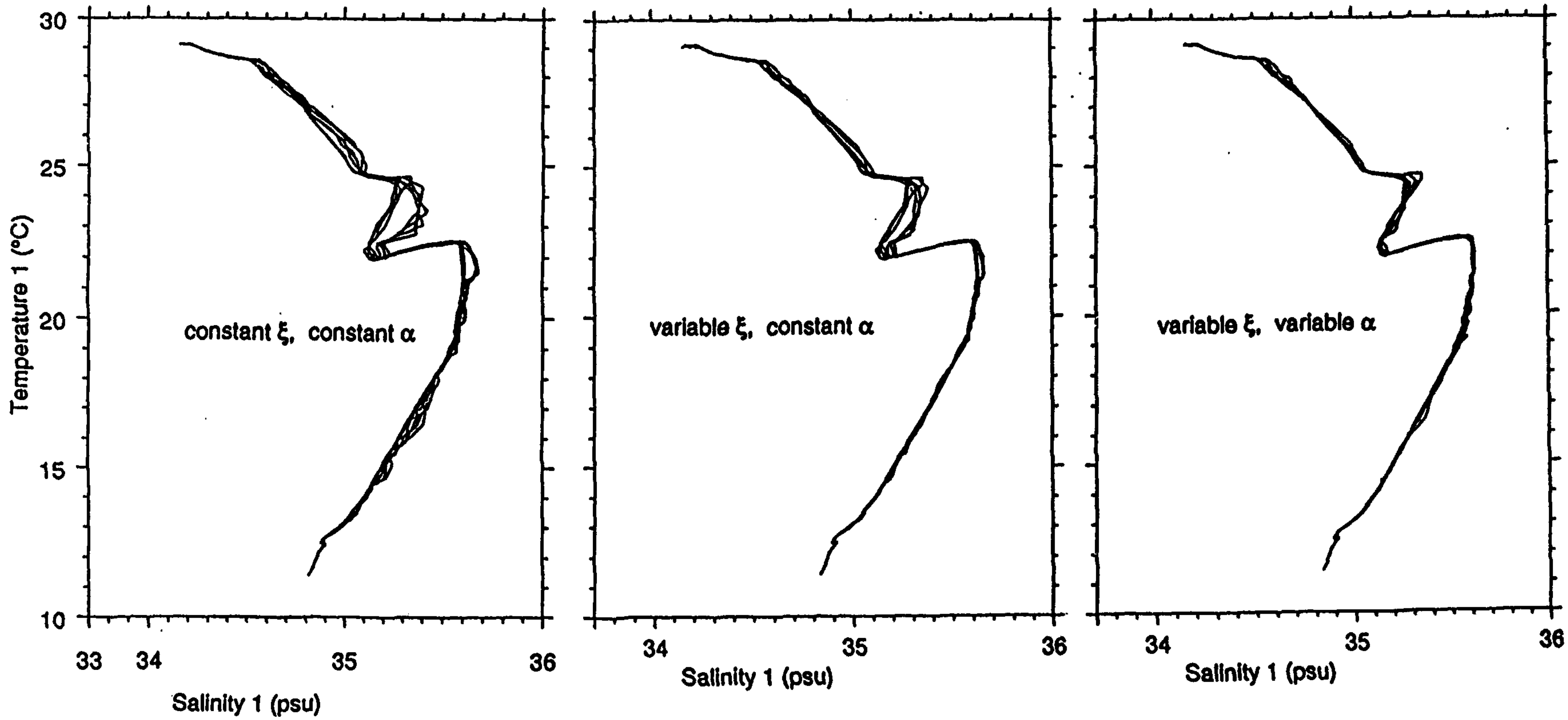

Figure 14. T-S characteristics for Seasoar data from the same hour (2000-2100 UTC, 13 Feb 1993), processed by three different methods: *left*, using a constant T/C offset ($\xi_1 = 0.0$), and a constant thermal anomaly amplitude ($\alpha = 0.045$); *center*, using variable ξ determined from T-C cross-correlation and constant α; *right*, using both variable ξ and a variable α which increases with ξ.

the 24-Hz data. Correlations are calculated for ±12 lags; the maximum correlation is almost always ≥0.85. The fractional value of the lag at maximum correlation is determined by fitting a parabola to the cross-correlation values. The resulting time series of the optimum primary and secondary alignment offsets (ξ_1 and ξ_2) for each tow are shown in Appendix A. Lag values greater than 12 and other outliers (obtained occasionally for data segments lasting <10 seconds) were not used in processing the data. Very large lags were obtained for many descending profiles of Tow 2) when the pump outlets were not properly connected, and hence data from descending profiles from this tow were discarded.

The edited values of the alignment offset were applied sequentially in reprocessing the 24-Hz T/C data. To reprocess data from depths shallower than 50 m, we used the ξ value determined from the preceding 120 to 50 dbar layer; for data deeper than 240 m, we used the ξ value determined from the preceding 180 to 240 dbar layer. Short segments with unreasonably large lags were processed with the lag obtained for the succeeding data segment.

To correct the 24 Hz conductivity data for the thermal mass of the conductivity cell, we used the standard algorithm with a fixed value for the thermal anomaly time constant (τ = 10 sec), and variable values for the thermal anomaly amplitude depending on the alignment offset:

$$\begin{array}{ll} \alpha_1 = 0.03 & \text{if } \xi_1 \le 0 \\ \alpha_1 = 0.03 + 0.03(\xi_1/2.75) & \text{if } \xi_1 > 0 \\ \alpha_2 = 0.03 & \text{if } \xi_2 \le 1.75 \\ \alpha_2 = 0.03 + 0.03(\xi_2\text{-}1.75)/2.75)) & \text{if } \xi_2 > 0, \end{array}$$

where the subscripts denote primary or secondary sensors. The corrected and realigned 24 Hz temperature and conductivity data are used to calculate 24-Hz salinity, and these are averaged to yield 1-second averages stored in hourly files. These procedures greatly reduce the systematic salinity differences (both bias and noise) between ascending and descending profiles (e.g. Figure 14). However, salinity data from descending profiles remains somewhat noisy, while the ascending data is almost always free of significant noise.

The reprocessed data from both sensor pairs were plotted to determine which pair provided the better data for each Seasoar tow. During Tow 2, with both sensor ducts disconnected from the outlet, there is evidence of stalling in the pumped sensor ducts during descent, but data from ascending profiles is apparently of good quality. For both Tows 2 and 3, with the malfunctioning secondary temperature sensor, data from the primary sensors is clearly preferable. During Tow 4, the

secondary sensor duct was disconnected from the outlet, and data from the primary sensors is clearly preferable. For Tows 5 and 6, the data from the two sensor pairs was of essentially the same quality, with only very subtle reasons to prefer the secondary sensors over the primary sensors.

Data Presentation

Successive hourly files of the reprocessed one-second average data were joined and clipped to yield a single data file for each section of the Standard Butterfly Pattern (Tables 9 and 10). Final processed data files contain unfiltered GPS latitude and longitude; pressure; temperature, salinity and sigma-t from the better sensor pair; date and time; and an integer representing flags (to indicate collection of a water sample from 5-m intake (thousands digit set to 1), missing GPS data filled by linear interpolation (tens digit set to 1), and to indicate port or starboard intake for the T/C sensor pair (ones digit set to 1 or 0, respectively)). We present consecutive figures of the Seasoar trajectory (time series of pressure, latitude and longitude) along each section. We also present summary figures of all of the 1-second data for each of the four standard sections as follows: ensembles of temperature profiles (both ascending and descending, except for Tow 2), salinity profiles (ascending profiles only), and T-S diagrams (for ascending profiles only). Vertical distributions of the temperature, salinity and sigma-t along each section were plotted using Don Denbo's PPlus program with a vertical grid spacing of 2 dbar and a horizontal spacing of 1 nm, and with a value of CAY= 5 for the smoothing parameter (combined spline and laplacian filter). For the temperature sections, we used both ascending and descending data, for all tows except Tow 2 where we used ascending data only. For the salinity and sigma-t sections, we used only ascending data for all tows.

CTD/Seasoar Comparison

T-S diagrams for the beginning and end of each Seasoar Tow are shown in Appendix B. Each diagram shows the T-S curve from both the conventional CTD cast and the preferred Seasoar sensors during Seasoar deployment or recovery. Seasoar deployment profiles are generally noisier than either the CTD profiles or Seasoar recovery profiles, probably because the Seasoar vehicle is tilted nose-upward during both deployment and recovery; since the ship is moving very slowly, observations during deployment are sometimes within the turbulent wake of the descending vehicle.

Acknowledgments

COARE Survey cruises on Wecoma were undertaken jointly by scientists from the University of Hawaii (R. Lukas, P. Hacker, and E. Firing) and Oregon State University (A. Huyer, M. Kosro and C. Paulson). Seasoar watchstanders on this cruise included personnel from both institutions (Eric Firing, Fred Bingham, Joanna Muench and Dail Rowe from UH; Jane Huyer, Bob Smith, Tim Holt, Jane Fleischbein, Marc Willis from OSU). We are deeply indebted to Wecoma's Marine Technicians: Marc Willis, Brian Wendler, Mike Hill and Tim Holt; this work would not have been possible without their skill and dedication. We are grateful to Nordeen Larson of SeaBird Electronics for his advice on installing the SeaBird sensors in the Seasoar vehicle and on data processing principles. Dail Rowe analyzed most of the salinity samples. Our COARE Survey cruises were supported by the National Science Foundation through its Ocean Sciences Division and by NOAA's Office of Global Programs under TOGA.

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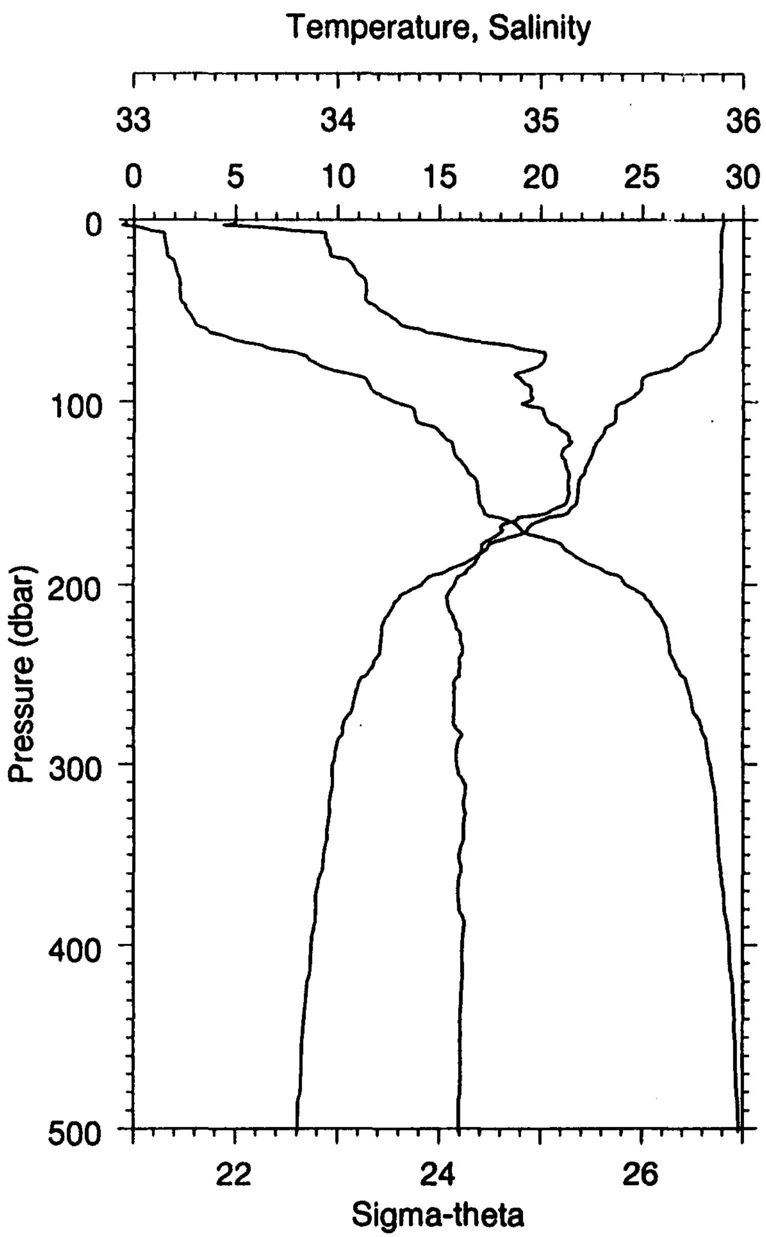
CTD DATA

CTD DATA

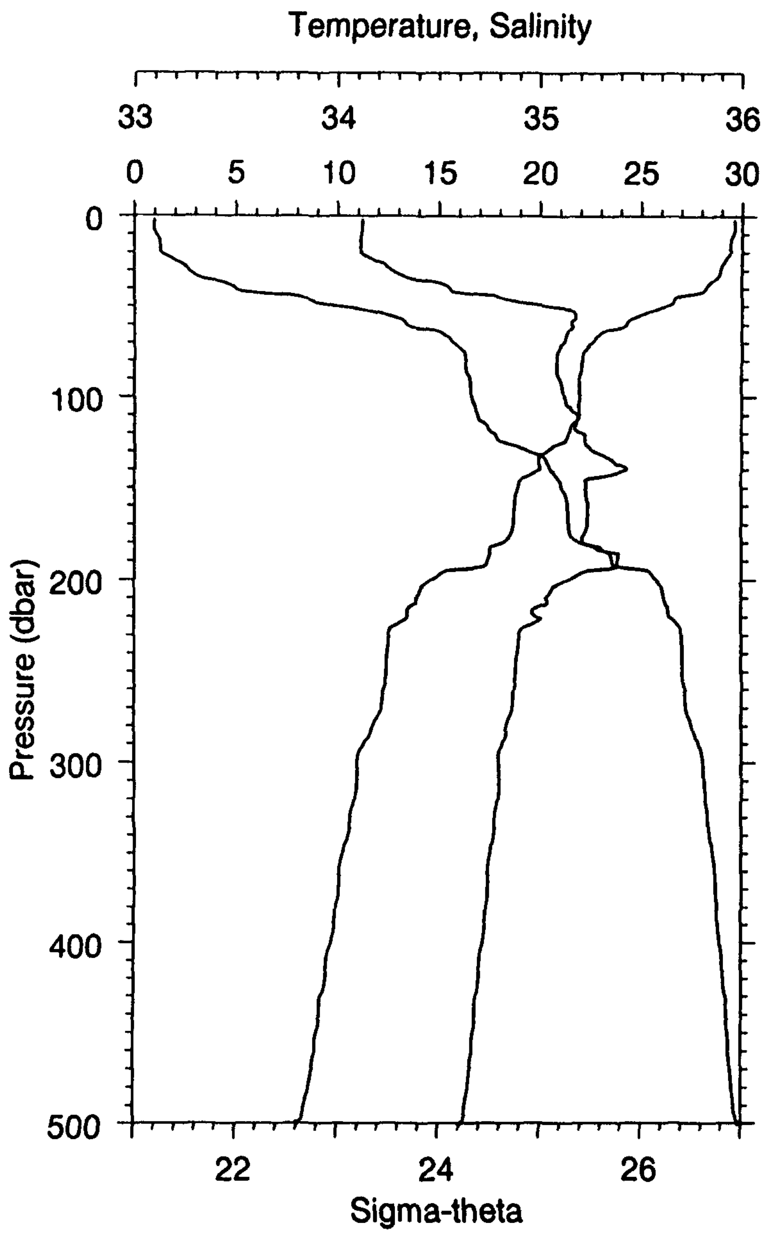
For each station, we present a plot of the vertical temperature, salinity, and sigma-t profiles, and a listing of the observed and derived variables at standard pressures. Header data includes the CTD Station Number, Latitude (in degrees and minutes; a negative degree integer indicates southern hemisphere), Longitude (degrees and minutes East), Date and Time (UTC), and Bottom Depth (in meters).



STA NO 1 LAT: 3 7.5 LONG: 156 7.1
26 JAN 1993 1439 GMT DEPTH 2700

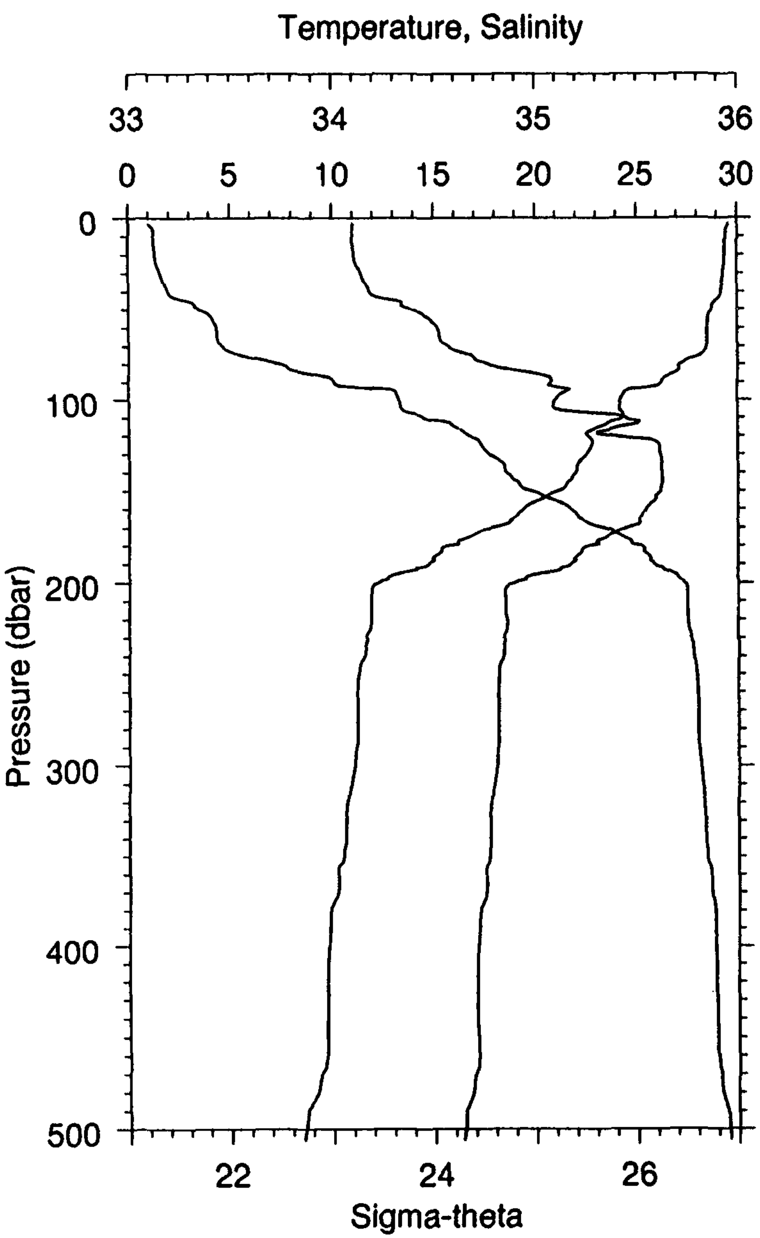
P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
1	29.042	33.492	29.041	20.920	684.7	0.068
10	28.910	33.935	28.908	21.298	648.9	0.667
20	28.896	33.961	28.891	21.323	647.0	1.315
30	28.900	34.096	28.893	21.423	637.8	1.955
40	28.916	34.143	28.907	21.454	635.4	2.591
50	28.864	34.206	28.852	21.520	629.5	3.224
60	28.739	34.397	28.725	21.705	612.3	3.848
70	28.066	34.877	28.049	22.288	556.9	4.436
80	26.707	34.993	26.688	22.813	507.1	4.961
90	24.973	34.918	24.954	23.295	461.3	5.440
100	24.144	34.930	24.123	23.554	437.0	5.893
110	23.668	35.028	23.645	23.769	416.9	6.314
120	22.954	35.139	22.930	24.061	389.4	6.715
130	22.487	35.104	22.461	24.168	379.5	7.098
140	22.105	35.140	22.077	24.304	366.9	7.470
150	21.829	35.138	21.799	24.380	360.0	7.832
160	21.361	35.043	21.330	24.437	354.9	8.190
170	19.310	34.811	19.279	24.806	319.7	8.525
180	17.328	34.707	17.298	25.219	280.2	8.822
190	15.823	34.656	15.793	25.531	250.5	9.089
200	14.161	34.578	14.132	25.834	221.5	9.323
225	12.173	34.585	12.143	26.240	182.9	9.815
250	11.497	34.596	11.466	26.376	170.4	10.260
275	10.349	34.570	10.317	26.562	152.8	10.663
300	9.746	34.586	9.712	26.678	142.0	11.029
325	9.596	34.623	9.559	26.732	137.4	11.378
350	9.306	34.597	9.267	26.760	135.1	11.718
375	8.951	34.596	8.911	26.816	130.0	12.049
400	8.717	34.615	8.674	26.868	125.4	12.368
425	8.469	34.608	8.425	26.902	122.5	12.679
450	8.296	34.606	8.249	26.927	120.4	12.983
475	8.226	34.606	8.177	26.938	119.8	13.283
500	8.049	34.596	7.997	26.957	118.2	13.580
502	8.048	34.596	7.996	26.957	118.3	13.603

Before Tow 1



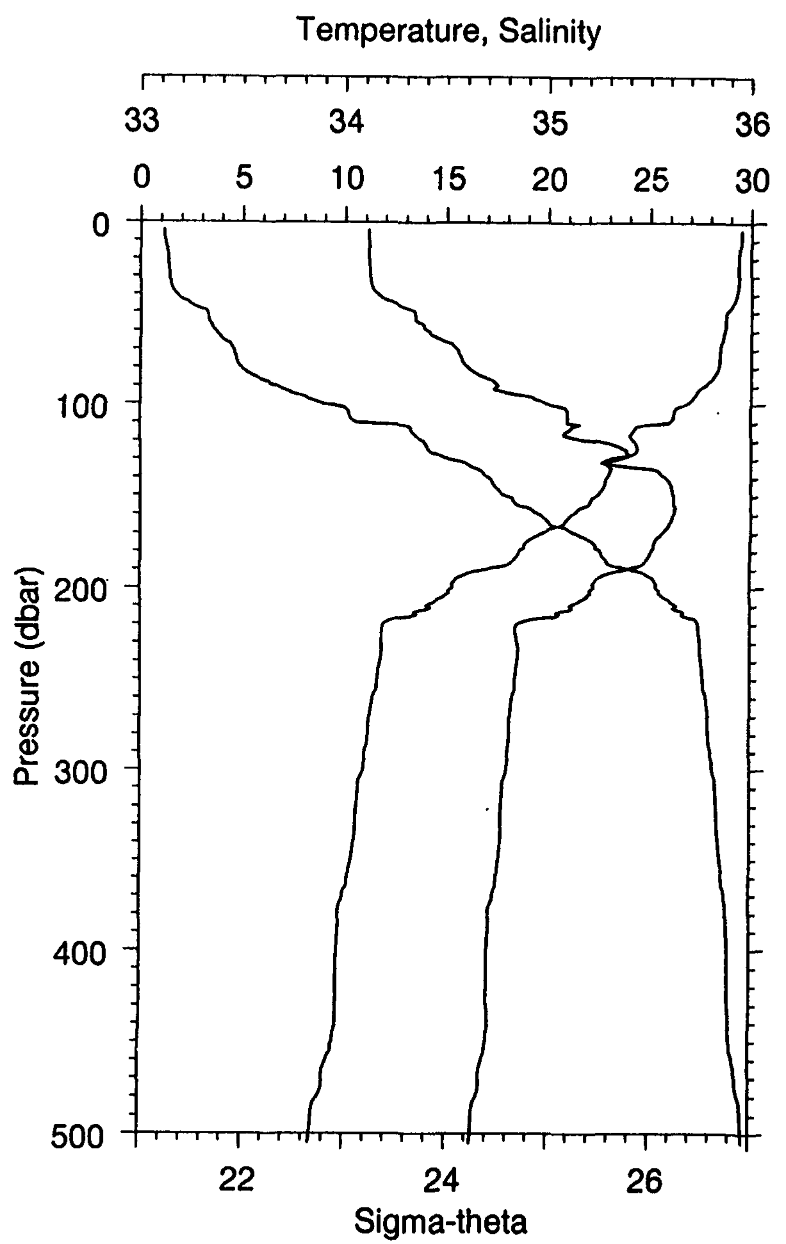
STA NO 2 LAT: -1 14.0 LONG: 156 5.9
27 JAN 1993 725 GMT DEPTH 2020

P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
2	29.636	34.119	29.635	21.192	658.7	0.132
10	29.573	34.116	29.570	21.212	657.2	0.659
20	29.424	34.113	29.419	21.260	653.0	1.313
30	28.949	34.267	28.942	21.535	627.1	1.951
40	28.209	34.557	28.200	21.999	583.2	2.558
50	26.256	35.036	26.244	22.986	489.1	3.092
60	24.288	35.158	24.275	23.681	423.1	3.537
70	22.587	35.118	22.573	24.147	379.0	3.932
80	22.081	35.082	22.065	24.263	368.3	4.303
90	21.958	35.097	21.940	24.309	364.3	4.671
100	21.976	35.121	21.956	24.324	363.4	5.034
110	21.949	35.190	21.927	24.384	358.0	5.395
120	21.424	35.215	21.401	24.549	342.6	5.747
130	20.330	35.269	20.306	24.887	310.7	6.077
140	20.012	35.431	19.986	25.096	291.2	6.374
150	18.953	35.230	18.926	25.217	279.8	6.657
160	18.750	35.239	18.722	25.276	274.6	6.934
170	18.702	35.238	18.672	25.288	273.8	7.208
180	18.179	35.214	18.148	25.400	263.4	7.479
190	17.422	35.385	17.390	25.717	233.5	7.721
200	14.649	35.136	14.619	26.161	190.7	7.931
225	12.819	34.940	12.789	26.389	169.1	8.385
250	12.447	34.883	12.414	26.419	166.8	8.802
275	12.034	34.855	11.998	26.477	161.8	9.215
300	11.023	34.798	10.986	26.622	148.2	9.601
325	10.746	34.786	10.707	26.662	144.8	9.969
350	10.298	34.756	10.257	26.718	139.8	10.326
375	10.061	34.743	10.017	26.748	137.3	10.671
400	9.733	34.720	9.687	26.787	133.9	11.010
425	9.371	34.695	9.323	26.827	130.3	11.339
450	9.000	34.672	8.951	26.870	126.5	11.659
475	8.696	34.651	8.645	26.902	123.7	11.972
500	8.028	34.613	7.977	26.974	116.7	12.276
499	7.965	34.610	7.914	26.981	115.9	12.264



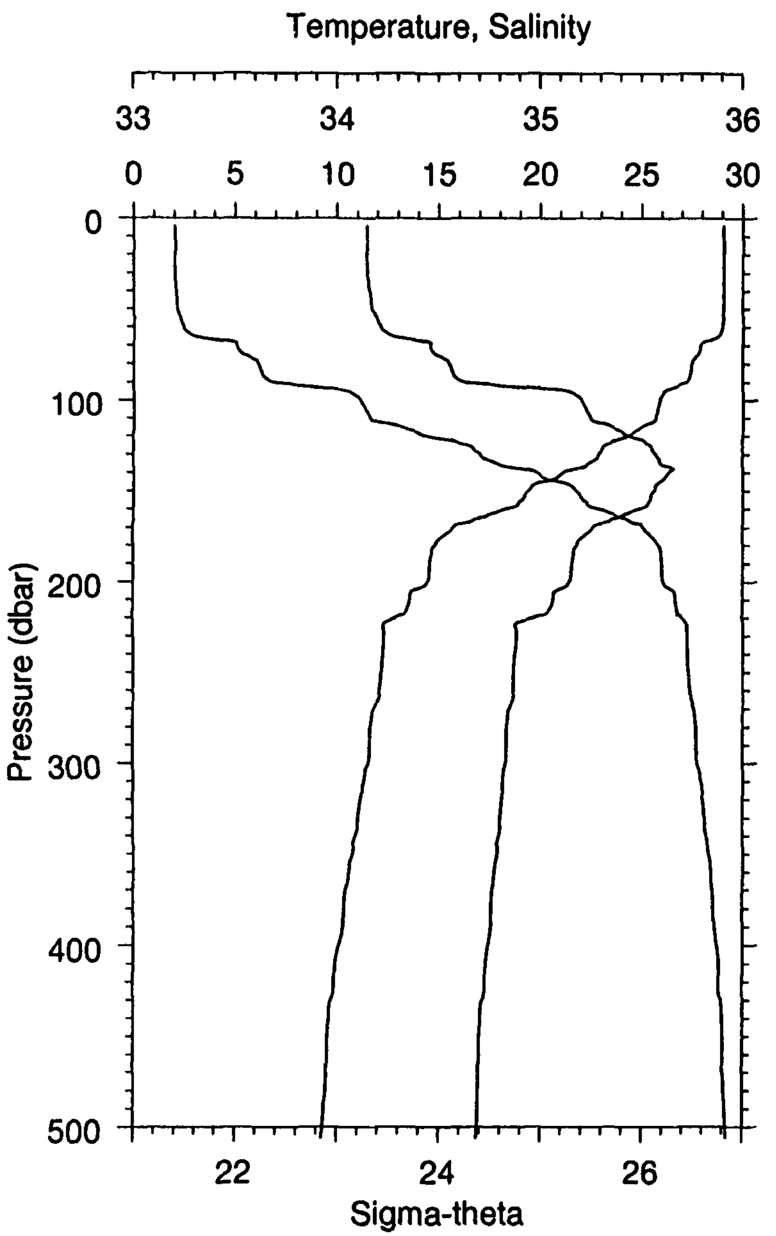
STA NO 3 LAT: -2 27.2 LONG: 156 7.8
29 JAN 1993 540 GMT DEPTH 1720

P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
3	29.585	34.103	29.584	21.197	658.2	0.197
10	29.424	34.099	29.421	21.249	653.6	0.656
20	29.404	34.110	29.399	21.265	652.6	1.309
30	29.322	34.144	29.314	21.319	647.8	1.960
40	29.203	34.184	29.193	21.390	641.5	2.604
50	28.740	34.391	28.728	21.700	612.3	3.231
60	28.517	34.519	28.503	21.870	596.5	3.832
70	28.462	34.571	28.445	21.929	591.3	4.427
80	27.137	34.769	27.119	22.508	536.3	4.997
90	26.248	35.080	26.228	23.025	487.3	5.508
100	24.217	35.101	24.196	23.661	426.8	5.955
110	24.296	35.447	24.273	23.900	404.5	6.376
120	22.576	35.378	22.552	24.350	361.8	6.753
130	22.538	35.616	22.512	24.543	343.9	7.104
140	21.988	35.623	21.960	24.704	328.9	7.438
150	21.133	35.619	21.104	24.938	306.9	7.757
160	19.399	35.544	19.370	25.343	268.4	8.042
170	17.857	35.453	17.828	25.663	238.0	8.299
180	15.594	35.263	15.566	26.050	200.9	8.518
190	14.735	35.173	14.707	26.170	189.6	8.714
200	12.264	34.896	12.238	26.463	161.2	8.887
225	11.840	34.857	11.810	26.515	156.8	9.281
250	11.279	34.818	11.248	26.589	150.1	9.664
275	11.184	34.812	11.150	26.602	149.5	10.038
300	11.035	34.804	10.998	26.624	147.9	10.411
325	10.649	34.774	10.610	26.670	143.9	10.775
350	10.519	34.769	10.477	26.689	142.7	11.134
375	9.985	34.735	9.941	26.756	136.5	11.483
400	9.778	34.712	9.732	26.773	135.3	11.821
425	9.718	34.708	9.669	26.780	135.1	12.159
450	9.681	34.713	9.629	26.790	134.7	12.496
475	9.327	34.692	9.274	26.833	130.9	12.830
500	8.645	34.647	8.591	26.906	123.7	13.146
502	8.575	34.641	8.521	26.913	123.1	13.171



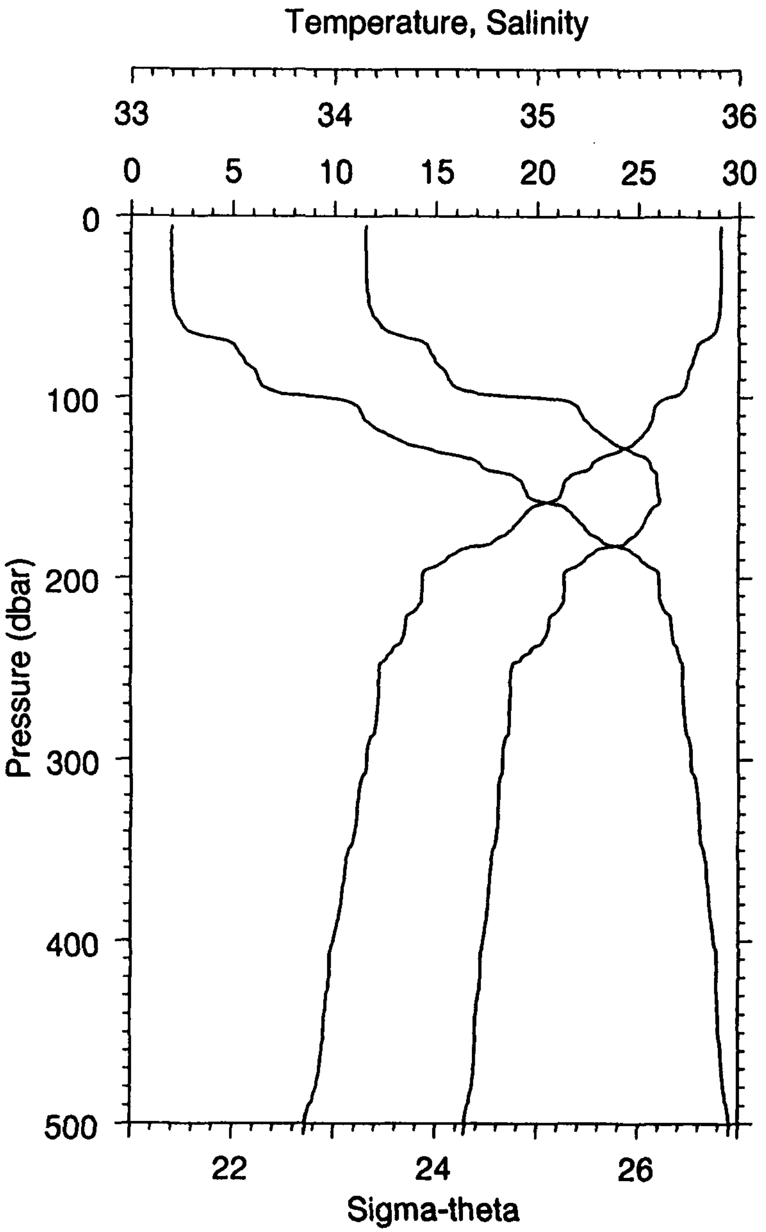
STA NO 4 LAT: -2 22.1 LONG: 156 2.0
29 JAN 1993 750 GMT DEPTH 1750

P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
4	29.510	34.112	29.509	21.230	655.1	0.262
10	29.495	34.114	29.493	21.236	654.8	0.655
20	29.391	34.118	29.386	21.275	651.6	1.308
30	29.381	34.125	29.374	21.285	651.1	1.960
40	29.271	34.160	29.261	21.349	645.5	2.609
50	28.764	34.341	28.752	21.654	616.7	3.242
60	28.679	34.411	28.664	21.736	609.3	3.856
70	28.477	34.550	28.461	21.908	593.3	4.458
80	28.382	34.603	28.363	21.980	586.9	5.049
90	27.643	34.752	27.622	22.333	553.5	5.621
100	26.767	35.000	26.744	22.802	509.1	6.154
110	25.956	35.092	25.931	23.126	478.5	6.642
120	24.232	35.253	24.207	23.773	417.1	7.071
130	23.401	35.290	23.374	24.046	391.3	7.480
140	22.858	35.583	22.829	24.427	355.4	7.850
150	22.398	35.619	22.368	24.586	340.6	8.199
160	21.154	35.617	21.123	24.931	307.9	8.524
170	19.704	35.564	19.672	25.280	274.9	8.818
180	18.597	35.508	18.565	25.521	252.0	9.079
190	16.959	35.388	16.928	25.830	222.6	9.323
200	15.369	35.229	15.338	26.075	199.2	9.528
225	11.879	34.844	11.849	26.497	158.5	9.969
250	11.660	34.842	11.628	26.537	155.2	10.362
275	11.258	34.817	11.223	26.593	150.4	10.743
300	10.983	34.801	10.946	26.631	147.2	11.115
325	10.614	34.773	10.575	26.675	143.4	11.476
350	10.377	34.761	10.335	26.708	140.8	11.832
375	9.856	34.724	9.812	26.768	135.2	12.178
400	9.684	34.706	9.638	26.784	134.1	12.515
425	9.657	34.704	9.608	26.787	134.4	12.851
450	9.512	34.706	9.461	26.813	132.4	13.185
475	8.971	34.669	8.919	26.872	126.8	13.507
500	8.403	34.630	8.350	26.930	121.2	13.815
504	8.357	34.626	8.304	26.934	120.8	13.863



STA NO 5   LAT: -1 52.2   LONG: 155 30.3
02 FEB 1993   2035 GMT   DEPTH 1940

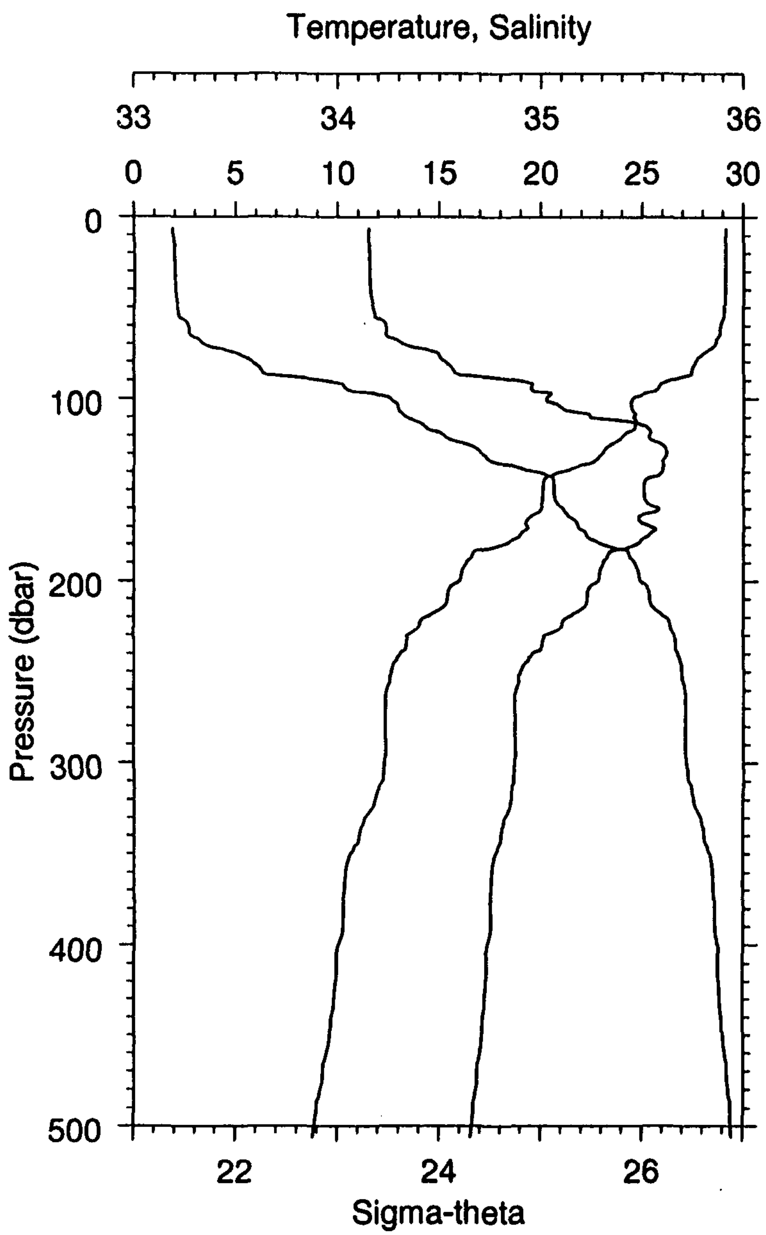
P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
4	29.062	34.145	29.061	21.404	638.4	0.255
10	29.052	34.146	29.049	21.409	638.2	0.638
20	29.059	34.146	29.054	21.407	638.9	1.277
30	29.063	34.150	29.056	21.410	639.1	1.916
40	29.063	34.159	29.053	21.417	638.9	2.555
50	29.057	34.170	29.045	21.428	638.3	3.194
60	28.975	34.213	28.961	21.489	633.0	3.829
70	27.936	34.461	27.919	22.018	582.8	4.444
80	27.495	34.551	27.476	22.229	563.0	5.018
90	27.234	34.631	27.213	22.374	549.6	5.577
100	25.884	35.203	25.862	23.231	468.0	6.070
110	25.687	35.247	25.662	23.326	459.4	6.534
120	24.334	35.436	24.308	23.881	406.8	6.966
130	22.866	35.571	22.839	24.415	356.1	7.340
140	21.095	35.634	21.068	24.960	304.4	7.678
150	19.410	35.562	19.383	25.353	267.0	7.962
160	18.244	35.479	18.217	25.587	245.0	8.221
170	15.702	35.258	15.676	26.021	203.4	8.444
180	14.784	35.179	14.757	26.164	189.8	8.640
190	14.540	35.156	14.512	26.199	186.8	8.828
200	14.415	35.141	14.385	26.215	185.5	9.015
225	12.277	34.876	12.247	26.446	163.5	9.448
250	12.160	34.868	12.127	26.463	162.5	9.855
275	11.694	34.838	11.658	26.528	156.7	10.256
300	11.535	34.828	11.497	26.551	155.1	10.646
325	11.084	34.806	11.043	26.617	149.3	11.025
350	10.742	34.786	10.700	26.663	145.3	11.394
375	10.377	34.761	10.332	26.709	141.3	11.751
400	10.078	34.743	10.032	26.746	138.1	12.102
425	9.866	34.728	9.816	26.771	136.1	12.443
450	9.539	34.699	9.488	26.804	133.3	12.779
475	9.467	34.695	9.413	26.812	132.9	13.112
500	9.308	34.689	9.252	26.834	131.2	13.442
505	9.263	34.685	9.207	26.839	130.9	13.508



STA NO 6 LAT: -1 51.9 LONG: 155 34.4
03 FEB 1993 2159 GMT DEPTH 1900

P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
5	29.095	34.154	29.093	21.400	638.9	0.319
10	29.098	34.153	29.096	21.399	639.2	0.639
20	29.104	34.154	29.099	21.399	639.7	1.278
30	29.102	34.156	29.095	21.401	639.9	1.918
40	29.101	34.158	29.091	21.404	640.2	2.558
50	29.069	34.174	29.056	21.427	638.4	3.198
60	28.927	34.230	28.913	21.517	630.3	3.833
70	28.016	34.441	28.000	21.977	586.7	4.447
80	27.712	34.495	27.693	22.117	573.7	5.026
90	27.456	34.562	27.435	22.251	561.4	5.592
100	26.438	34.996	26.416	22.902	499.5	6.140
110	25.771	35.226	25.747	23.284	463.4	6.612
120	25.274	35.315	25.248	23.505	442.7	7.068
130	23.966	35.478	23.938	24.023	393.6	7.489
140	22.516	35.576	22.488	24.519	346.6	7.852
150	21.315	35.599	21.286	24.873	313.1	8.174
160	19.879	35.585	19.850	25.249	277.5	8.476
170	18.973	35.527	18.943	25.440	259.4	8.744
180	17.853	35.444	17.822	25.657	238.9	8.994
190	15.586	35.243	15.556	26.036	202.6	9.210
200	14.396	35.138	14.366	26.217	185.4	9.402
225	13.548	35.061	13.516	26.336	174.5	9.857
250	12.268	34.875	12.235	26.448	164.0	10.282
275	12.139	34.866	12.103	26.466	162.9	10.691
300	11.647	34.834	11.609	26.535	156.7	11.090
325	11.163	34.811	11.122	26.607	150.3	11.474
350	10.756	34.786	10.713	26.661	145.5	11.846
375	10.397	34.762	10.352	26.706	141.6	12.205
400	9.988	34.736	9.941	26.756	137.0	12.553
425	9.755	34.720	9.706	26.783	134.8	12.891
450	9.511	34.697	9.460	26.807	133.0	13.225
475	9.226	34.685	9.173	26.844	129.7	13.553
500	8.607	34.645	8.553	26.911	123.3	13.869
505	8.575	34.641	8.521	26.913	123.1	13.931

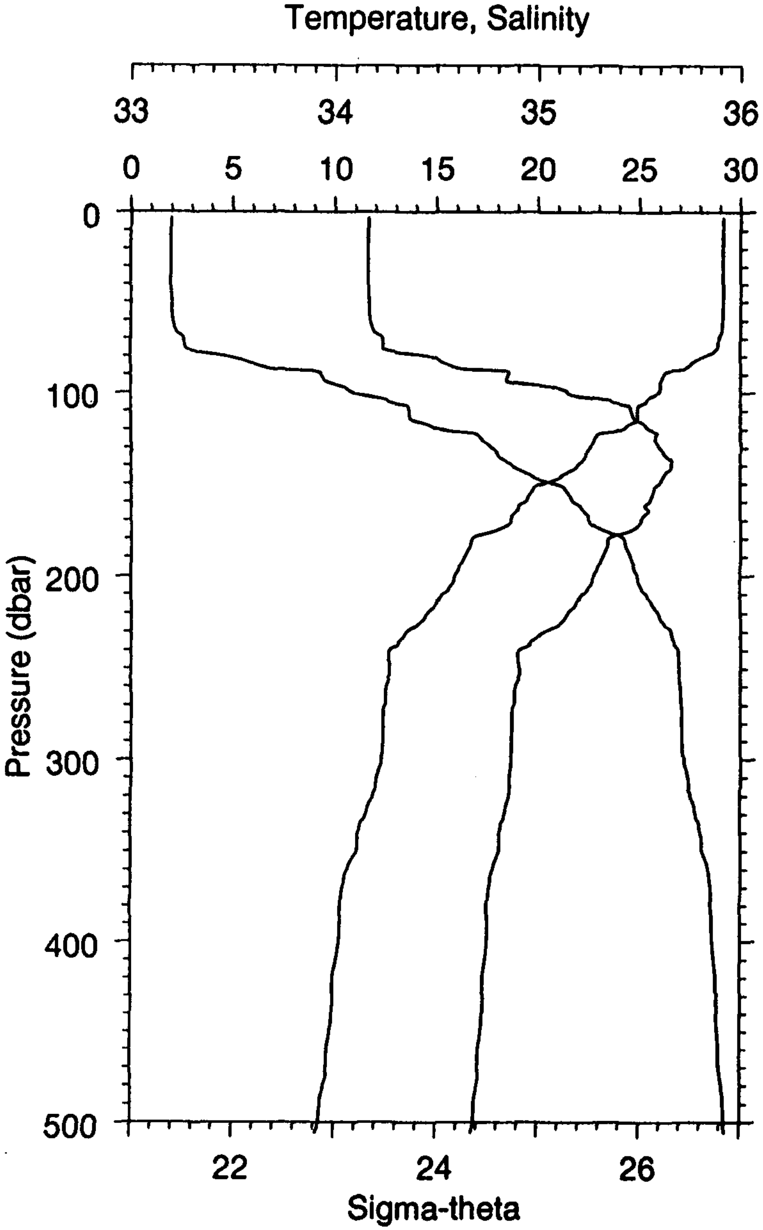
Before Tow 4



STA NO 7 LAT: -1 17.2 LONG: 156 9.6
07 FEB 1993 3 GMT DEPTH 1980

P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
6	29.162	34.152	29.160	21.376	641.2	0.385
10	29.150	34.152	29.148	21.381	641.0	0.641
20	29.117	34.153	29.112	21.393	640.3	1.281
30	29.111	34.154	29.104	21.397	640.4	1.921
40	29.103	34.158	29.093	21.403	640.3	2.562
50	29.074	34.174	29.062	21.425	638.6	3.201
60	28.901	34.235	28.886	21.530	629.0	3.836
70	28.636	34.320	28.619	21.682	614.9	4.460
80	27.645	34.531	27.627	22.165	569.1	5.049
90	26.313	34.887	26.293	22.859	503.2	5.602
100	24.505	35.024	24.484	23.517	440.6	6.074
110	24.536	35.239	24.513	23.671	426.4	6.508
120	24.042	35.533	24.017	24.042	391.4	6.916
130	22.969	35.619	22.942	24.421	355.6	7.288
140	20.957	35.599	20.930	24.970	303.3	7.624
150	20.106	35.510	20.078	25.131	288.3	7.915
160	20.003	35.582	19.974	25.214	280.8	8.201
170	19.322	35.543	19.292	25.362	266.9	8.475
180	18.108	35.465	18.077	25.610	243.4	8.732
190	16.299	35.305	16.268	25.922	213.7	8.954
200	15.955	35.280	15.923	25.982	208.2	9.165
225	13.988	35.101	13.955	26.276	180.4	9.652
250	12.635	34.897	12.601	26.393	169.3	10.086
275	12.359	34.872	12.323	26.428	166.6	10.504
300	12.301	34.871	12.261	26.439	166.2	10.921
325	11.685	34.845	11.643	26.537	157.2	11.328
350	10.642	34.779	10.600	26.676	144.0	11.704
375	10.297	34.753	10.253	26.716	140.5	12.058
400	10.034	34.736	9.987	26.749	137.8	12.408
425	9.882	34.727	9.833	26.768	136.4	12.751
450	9.604	34.708	9.552	26.800	133.7	13.089
475	9.248	34.685	9.195	26.840	130.1	13.418
500	8.867	34.661	8.812	26.883	126.2	13.738
501	8.853	34.659	8.798	26.884	126.1	13.750

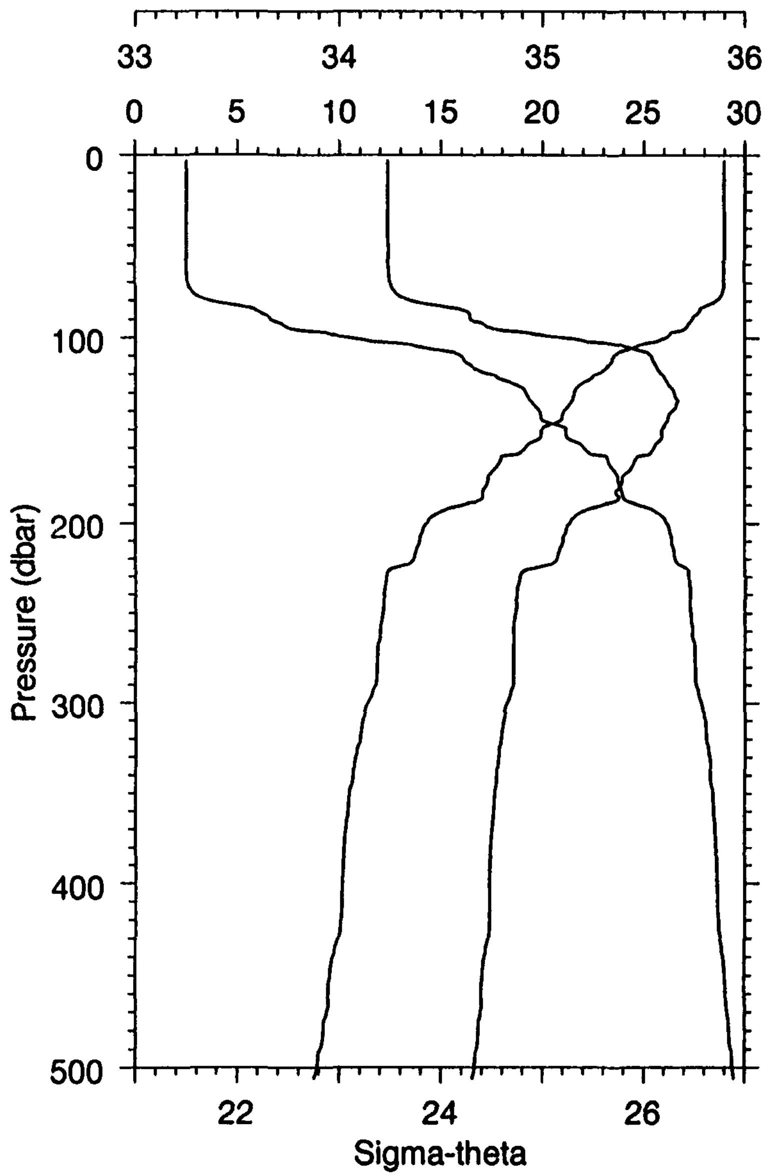
After Tow 4



STA NO 8 LAT: -1 14.0 LONG: 156 6.0
07 FEB 1993 1930 GMT DEPTH 2020

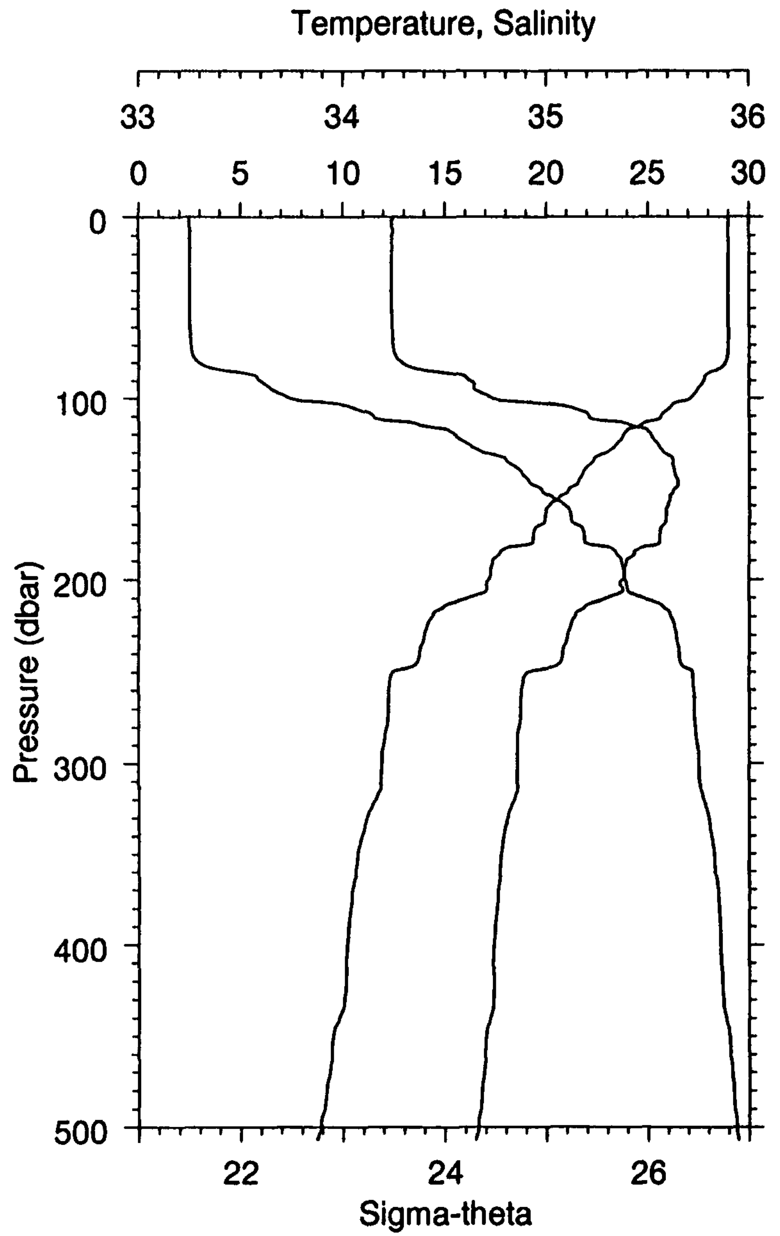
P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
3	29.133	34.162	29.133	21.393	639.5	0.192
10	29.139	34.162	29.137	21.391	639.9	0.640
20	29.137	34.162	29.132	21.393	640.2	1.280
30	29.136	34.162	29.129	21.395	640.6	1.920
40	29.149	34.162	29.140	21.391	641.4	2.561
50	29.130	34.167	29.118	21.402	640.9	3.203
60	29.114	34.172	29.099	21.412	640.4	3.844
70	28.938	34.232	28.921	21.516	630.9	4.481
80	28.203	34.465	28.184	21.935	591.2	5.103
90	26.209	34.852	26.189	22.864	502.6	5.655
100	25.894	35.142	25.871	23.183	472.7	6.146
110	24.899	35.460	24.875	23.729	420.9	6.586
120	24.066	35.554	24.041	24.050	390.6	6.998
130	22.507	35.601	22.481	24.540	344.2	7.355
140	21.938	35.659	21.910	24.745	325.0	7.690
150	20.272	35.600	20.244	25.156	286.0	7.999
160	19.398	35.552	19.369	25.349	267.8	8.273
170	18.674	35.509	18.644	25.502	253.4	8.531
180	16.745	35.345	16.716	25.848	220.5	8.770
190	16.387	35.319	16.356	25.912	214.6	8.988
200	15.924	35.276	15.892	25.985	207.8	9.199
225	14.194	35.114	14.161	26.242	183.6	9.692
250	12.679	34.906	12.645	26.391	169.5	10.126
275	12.393	34.871	12.356	26.421	167.3	10.547
300	12.268	34.864	12.228	26.440	166.1	10.966
325	11.647	34.843	11.605	26.543	156.7	11.371
350	11.072	34.806	11.029	26.620	149.6	11.751
375	10.327	34.754	10.282	26.711	141.0	12.110
400	10.222	34.748	10.174	26.726	140.1	12.462
425	9.910	34.729	9.861	26.764	136.8	12.807
450	9.788	34.720	9.736	26.779	135.9	13.149
475	9.597	34.708	9.543	26.801	134.1	13.486
500	9.242	34.685	9.186	26.842	130.4	13.815
506	9.092	34.675	9.036	26.858	128.9	13.893

Before Tow 5



STA NO 9 LAT: -2 0.5 LONG: 155 40.4
12 FEB 1993 2059 GMT DEPTH 1890

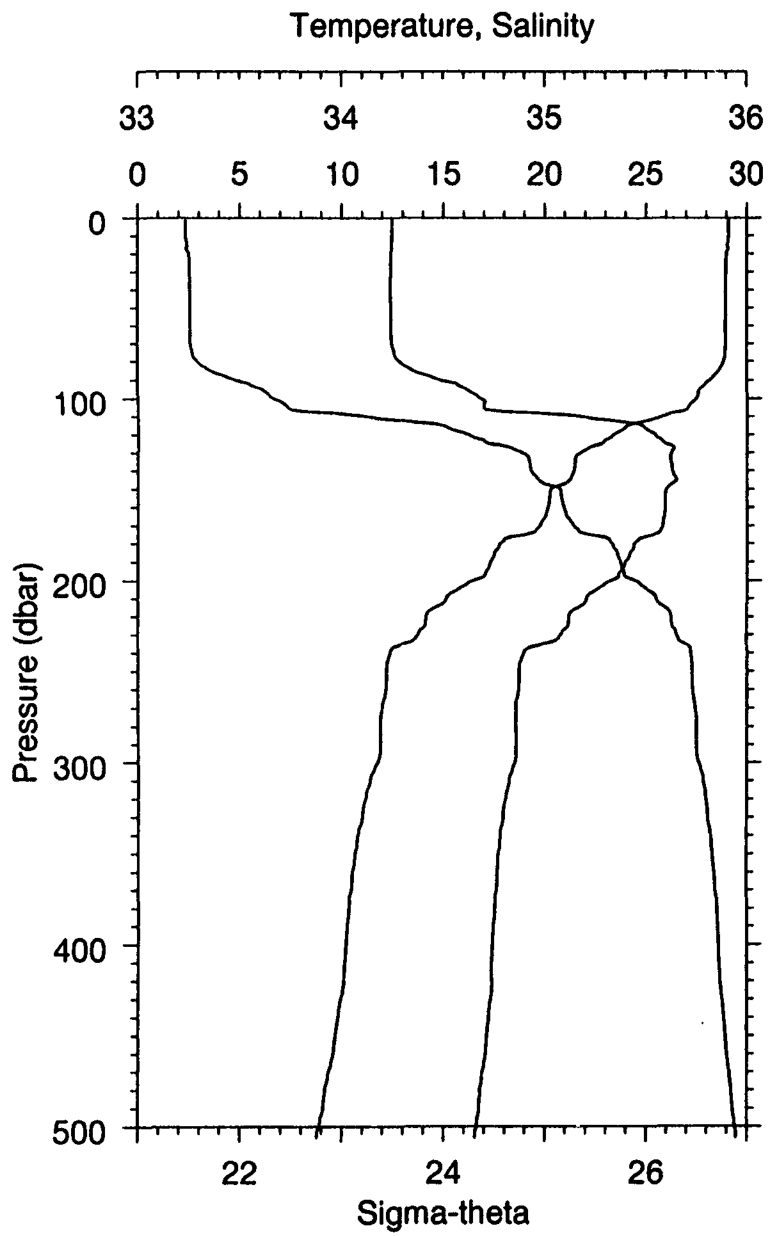
P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
3	28.975	34.235	28.974	21.501	629.1	0.189
10	28.975	34.236	28.972	21.502	629.3	0.629
20	28.973	34.236	28.968	21.504	629.7	1.259
30	28.978	34.236	28.971	21.503	630.2	1.889
40	28.981	34.237	28.971	21.503	630.7	2.519
50	28.988	34.240	28.976	21.504	631.1	3.150
60	28.991	34.241	28.976	21.505	631.5	3.781
70	28.976	34.250	28.959	21.517	630.8	4.412
80	28.574	34.354	28.555	21.729	610.9	5.038
90	27.393	34.643	27.372	22.332	553.6	5.611
100	26.043	35.130	26.021	23.127	478.0	6.135
110	23.513	35.540	23.490	24.202	375.6	6.553
120	22.660	35.594	22.635	24.491	348.5	6.919
130	21.573	35.653	21.548	24.842	315.3	7.248
140	21.067	35.640	21.041	24.972	303.3	7.558
150	19.959	35.590	19.931	25.231	278.8	7.852
160	19.149	35.550	19.120	25.412	261.8	8.125
170	17.747	35.443	17.719	25.682	236.1	8.370
180	17.217	35.384	17.187	25.766	228.4	8.601
190	16.168	35.301	16.138	25.948	211.1	8.825
200	14.314	35.136	14.285	26.232	183.8	9.018
225	12.817	34.974	12.787	26.416	166.6	9.463
250	12.146	34.867	12.113	26.465	162.3	9.871
275	11.873	34.856	11.838	26.509	158.7	10.272
300	11.402	34.826	11.364	26.574	152.9	10.665
325	10.874	34.785	10.834	26.639	147.1	11.039
350	10.514	34.766	10.472	26.688	142.8	11.402
375	10.284	34.749	10.239	26.715	140.6	11.756
400	10.158	34.738	10.111	26.728	139.8	12.107
425	10.050	34.738	10.000	26.747	138.5	12.455
450	9.560	34.706	9.509	26.805	133.1	12.794
475	9.235	34.684	9.182	26.842	129.9	13.124
500	8.915	34.664	8.860	26.878	126.7	13.445
505	8.807	34.656	8.752	26.889	125.7	13.508



STA NO 10   LAT: -2 0.4   LONG: 155 40.8
12 FEB 1993   2320 GMT   DEPTH 1880

P (DB)	T (C)	S	POT T (C)	SIGMA THETA	SVA (CL/T)	DYN HT (J/KG)
1	29.003	34.249	29.003	21.502	629.0	0.063
10	28.977	34.239	28.975	21.503	629.2	0.629
20	28.975	34.239	28.970	21.505	629.5	1.258
30	28.976	34.237	28.969	21.504	630.1	1.888
40	28.977	34.238	28.968	21.505	630.5	2.519
50	28.979	34.239	28.967	21.506	630.8	3.149
60	28.979	34.242	28.964	21.509	631.0	3.780
70	28.971	34.249	28.954	21.518	630.7	4.411
80	28.831	34.294	28.812	21.599	623.4	5.040
90	27.768	34.628	27.747	22.199	566.3	5.632
100	27.097	34.741	27.074	22.501	537.9	6.186
110	25.655	35.210	25.630	23.308	461.1	6.674
120	23.789	35.513	23.764	24.101	385.7	7.092
130	22.994	35.578	22.967	24.383	359.2	7.466
140	21.868	35.630	21.840	24.743	325.2	7.804
150	21.161	35.639	21.132	24.946	306.1	8.122
160	20.165	35.605	20.135	25.189	283.2	8.418
170	19.711	35.581	19.679	25.291	273.8	8.696
180	19.324	35.559	19.292	25.375	266.1	8.964
190	17.347	35.392	17.316	25.741	231.2	9.204
200	17.158	35.376	17.125	25.774	228.3	9.434
225	14.107	35.116	14.075	26.262	181.8	9.942
250	12.410	34.905	12.376	26.443	164.5	10.386
275	12.195	34.870	12.159	26.458	163.6	10.795
300	11.899	34.855	11.860	26.504	159.8	11.199
325	11.372	34.822	11.331	26.577	153.2	11.594
350	10.734	34.777	10.691	26.658	145.8	11.966
375	10.424	34.758	10.379	26.698	142.3	12.326
400	10.213	34.741	10.166	26.722	140.5	12.680
425	10.111	34.739	10.061	26.738	139.4	13.030
450	9.523	34.703	9.471	26.809	132.7	13.371
475	9.224	34.683	9.171	26.843	129.8	13.700
500	8.913	34.664	8.859	26.878	126.7	14.021
504	8.782	34.654	8.728	26.891	125.4	14.072

Before Tow 6



STA NO 11 LAT: -1 59.3 LONG: 155 43.4
13 FEB 93 440 GMT DEPTH 1875

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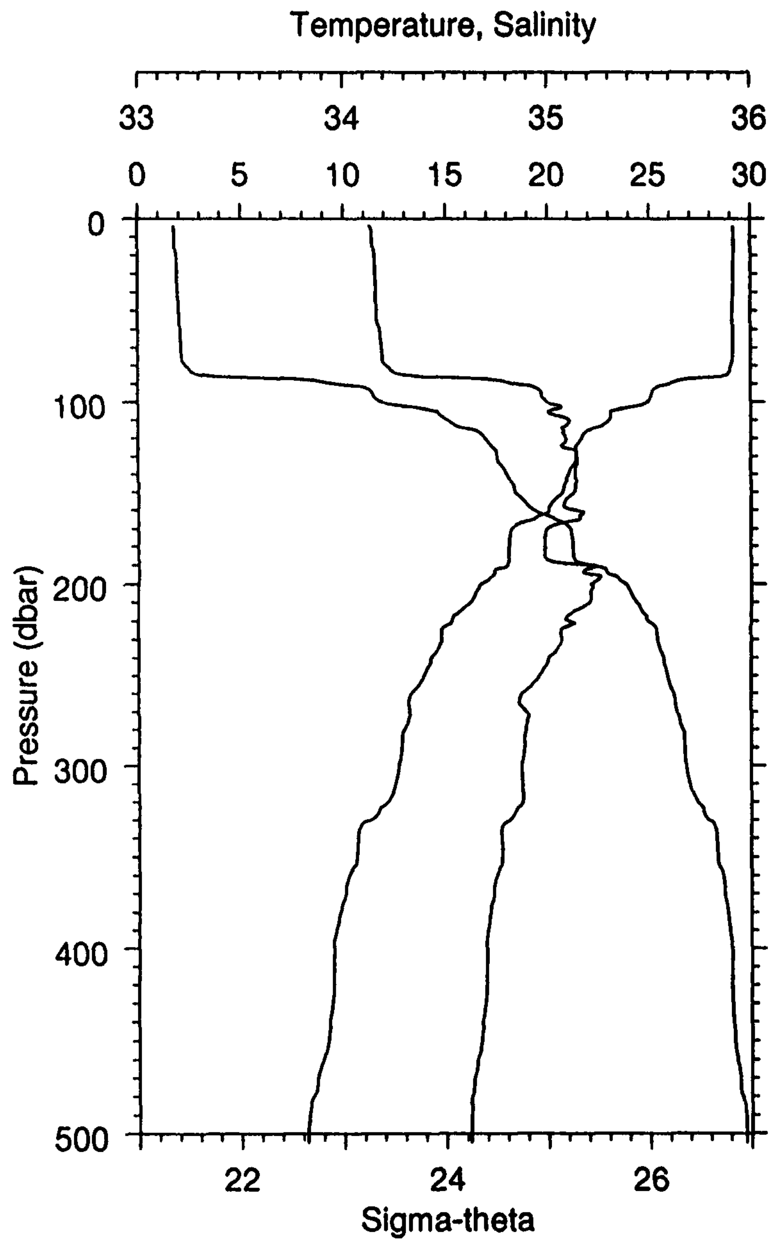
1	29.104	34.247	29.103	21.467	632.3	0.063
10	29.100	34.247	29.098	21.468	632.6	0.632
20	28.986	34.240	28.982	21.502	629.8	1.264
30	28.972	34.241	28.965	21.509	629.7	1.894
40	28.957	34.238	28.947	21.512	629.8	2.523
50	28.959	34.241	28.947	21.514	630.1	3.153
60	28.963	34.243	28.948	21.516	630.4	3.784
70	28.965	34.246	28.948	21.518	630.7	4.414
80	28.853	34.284	28.834	21.584	624.8	5.043
90	28.186	34.488	28.165	21.958	589.4	5.653
100	27.500	34.685	27.476	22.330	554.3	6.221
110	25.763	35.199	25.738	23.267	465.1	6.748
120	23.368	35.547	23.343	24.251	371.4	7.155
130	21.737	35.626	21.711	24.776	321.6	7.502
140	21.435	35.631	21.408	24.864	313.6	7.818
150	20.284	35.599	20.256	25.152	286.4	8.121
160	20.142	35.595	20.112	25.187	283.4	8.407
170	19.751	35.584	19.720	25.283	274.6	8.686
180	17.797	35.439	17.766	25.667	237.9	8.943
190	17.316	35.395	17.284	25.750	230.3	9.177
200	16.450	35.327	16.418	25.903	215.8	9.403
225	14.104	35.116	14.071	26.262	181.7	9.888
250	12.209	34.873	12.176	26.457	163.1	10.311
275	11.920	34.857	11.884	26.501	159.4	10.716
300	11.796	34.855	11.757	26.523	158.0	11.114
325	11.090	34.799	11.050	26.610	149.9	11.496
350	10.688	34.773	10.645	26.663	145.3	11.866
375	10.386	34.756	10.341	26.703	141.8	12.225
400	10.222	34.742	10.174	26.721	140.6	12.578
425	10.061	34.738	10.011	26.746	138.6	12.928
450	9.699	34.715	9.648	26.789	134.8	13.269
475	9.295	34.688	9.241	26.835	130.6	13.601
500	8.902	34.664	8.847	26.880	126.5	13.922
505	8.784	34.655	8.730	26.892	125.4	13.985



STA NO 12 LAT: 0 8.5 LONG: 156 5.9
15 FEB 1993 2130 GMT DEPTH 1925

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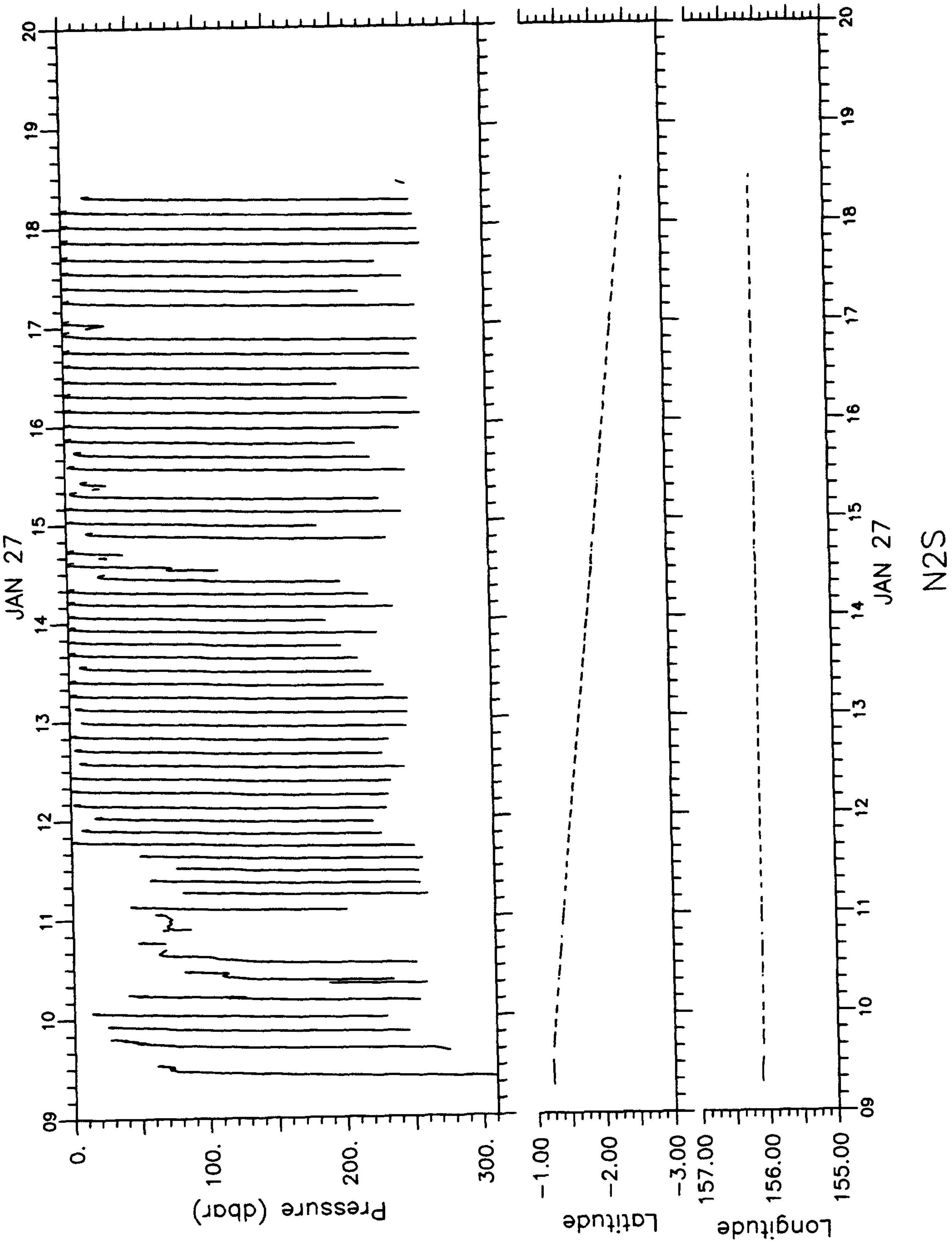
10	29.192	34.141	29.189	21.358	643.1	0.643
20	29.165	34.151	29.160	21.376	641.9	1.286
30	29.163	34.156	29.156	21.381	641.9	1.928
40	29.146	34.159	29.136	21.390	641.5	2.570
50	29.122	34.165	29.110	21.403	640.8	3.211
60	29.127	34.177	29.112	21.412	640.4	3.852
70	29.127	34.186	29.110	21.419	640.2	4.492
80	29.039	34.211	29.020	21.467	636.0	5.131
90	25.943	34.846	25.923	22.943	495.0	5.720
100	24.866	34.998	24.845	23.388	452.9	6.185
110	23.011	35.109	22.989	24.022	392.7	6.598
120	21.659	35.089	21.635	24.389	358.0	6.972
130	21.393	35.145	21.368	24.505	347.2	7.323
140	21.028	35.137	21.001	24.599	338.6	7.667
150	20.722	35.128	20.693	24.676	331.7	8.001
160	20.049	35.143	20.020	24.867	313.7	8.324
170	18.208	34.995	18.179	25.225	279.6	8.618
180	18.096	34.986	18.065	25.246	277.9	8.897
190	18.018	35.225	17.985	25.449	259.0	9.172
200	16.651	35.207	16.619	25.765	229.0	9.415
225	14.802	35.064	14.768	26.073	199.9	9.953
250	13.913	34.955	13.877	26.179	190.2	10.443
275	13.130	34.896	13.091	26.295	179.6	10.904
300	12.697	34.871	12.656	26.362	173.7	11.343
325	11.708	34.840	11.666	26.529	158.0	11.763
350	10.639	34.774	10.597	26.672	144.4	12.133
375	9.910	34.721	9.866	26.757	136.3	12.483
400	9.498	34.696	9.452	26.807	131.9	12.817
425	9.474	34.694	9.426	26.810	132.1	13.147
450	9.211	34.670	9.161	26.834	130.1	13.475
475	8.661	34.632	8.610	26.892	124.6	13.793
500	8.226	34.618	8.174	26.948	119.3	14.095
505	8.227	34.619	8.175	26.948	119.4	14.155

End of Tow 6

SEASOAR TRAJECTORIES



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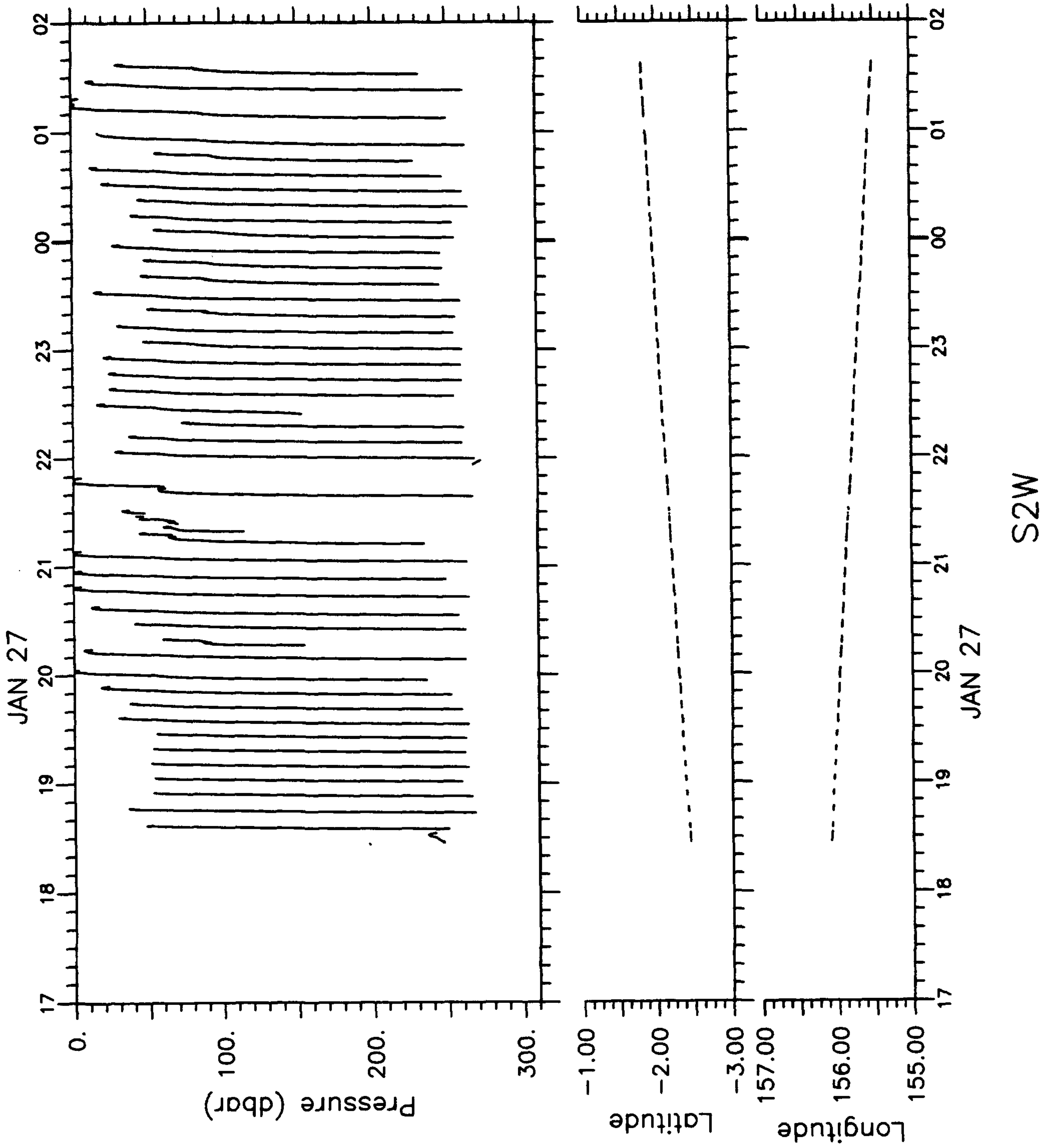
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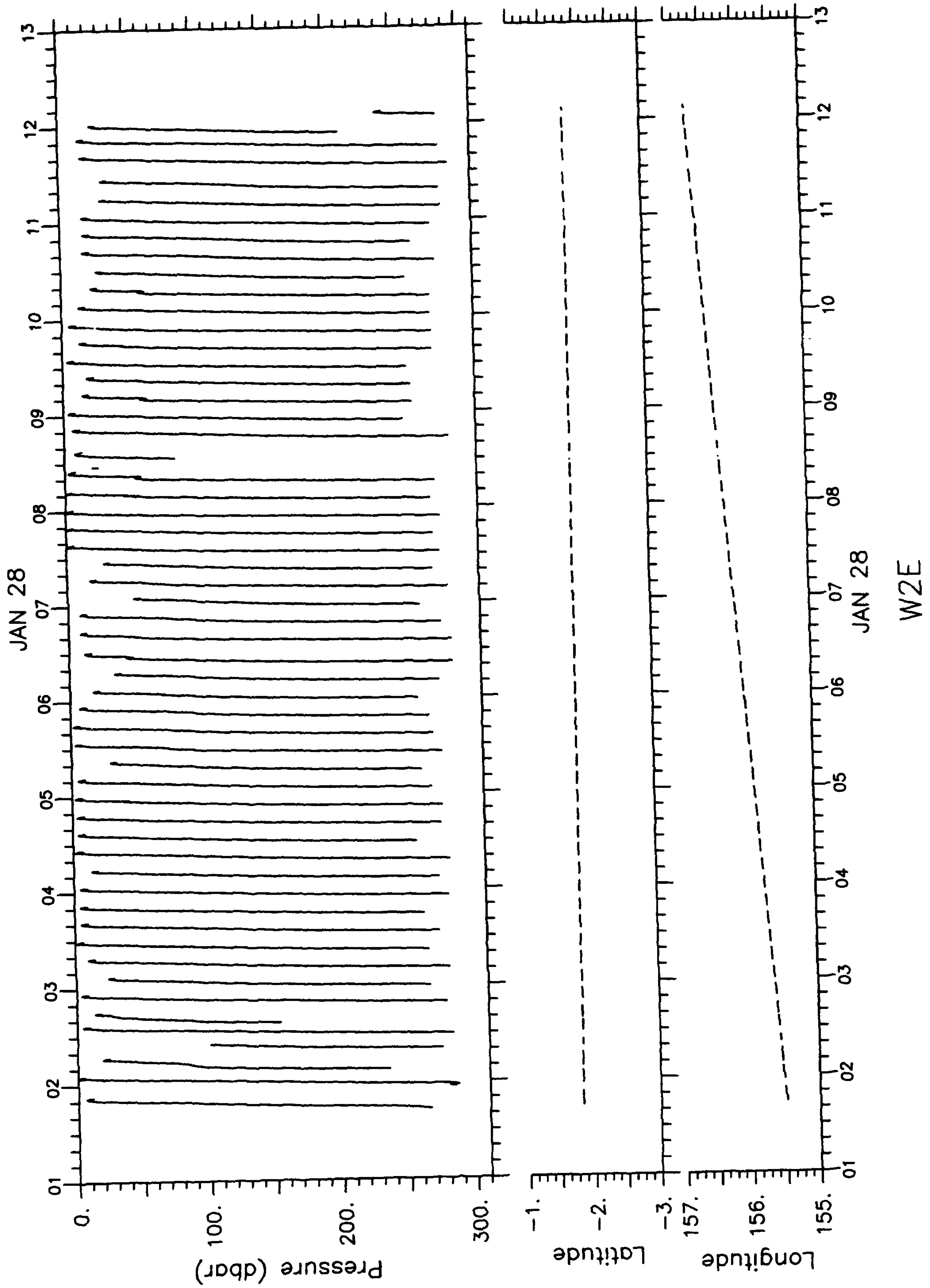
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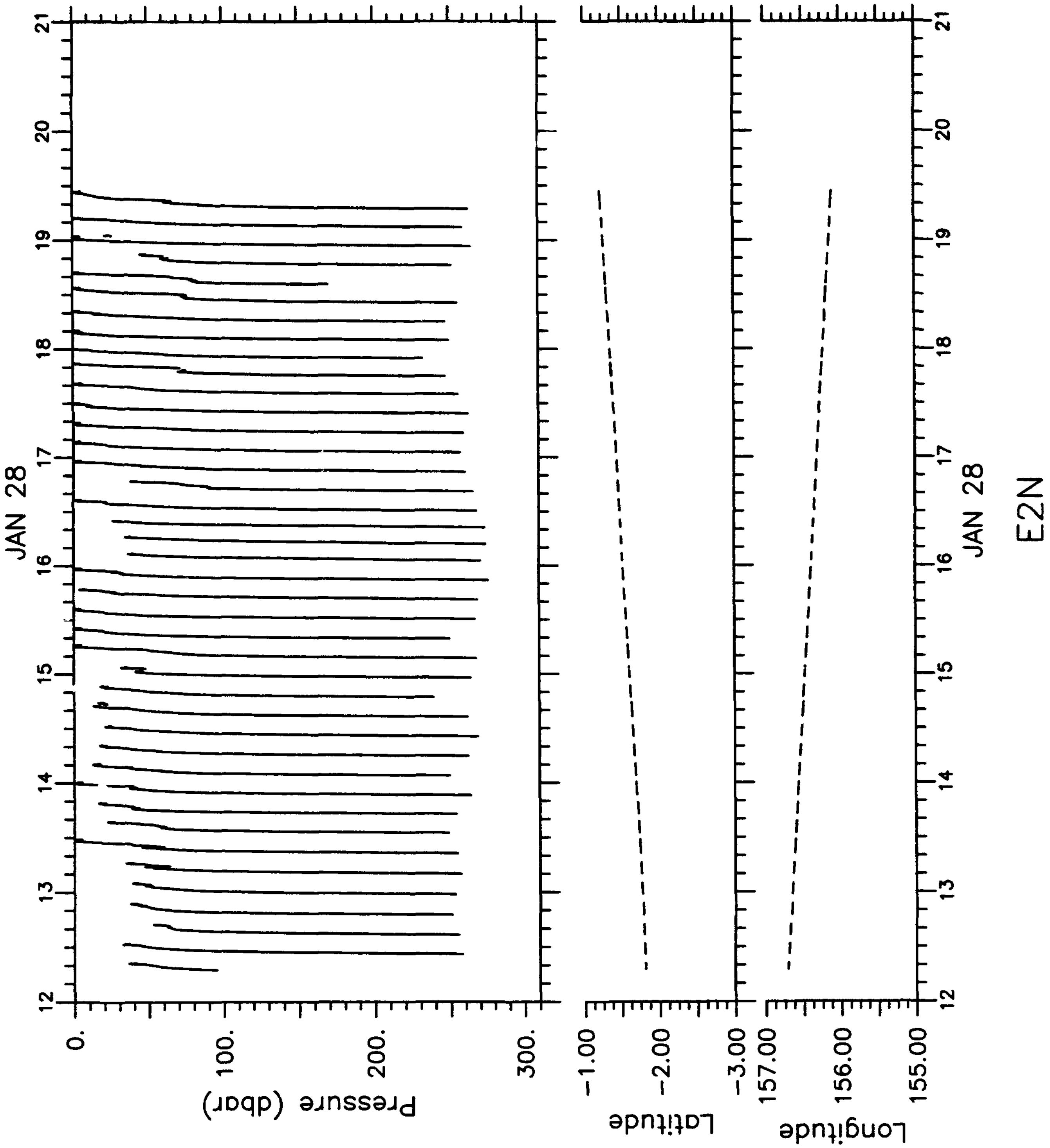
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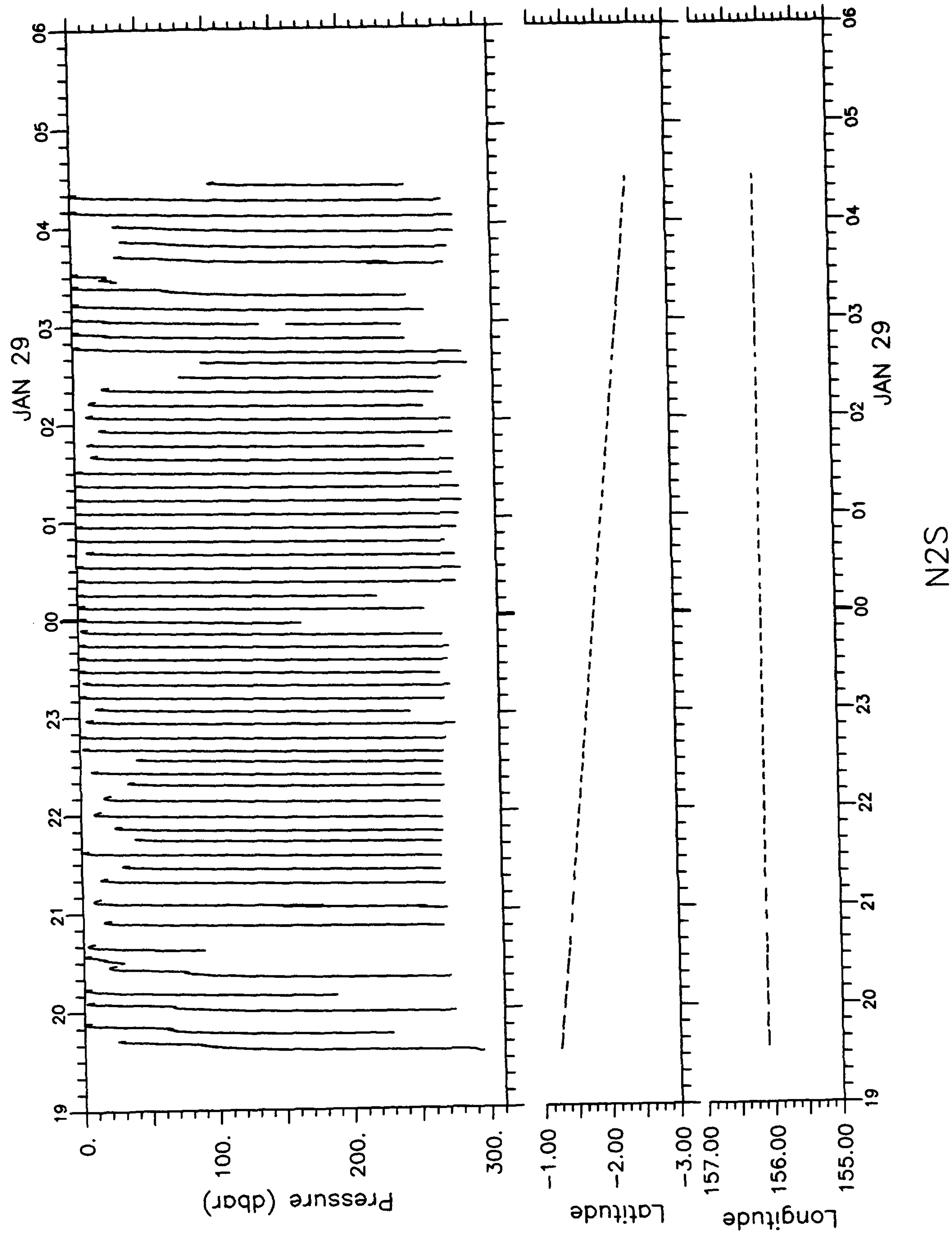
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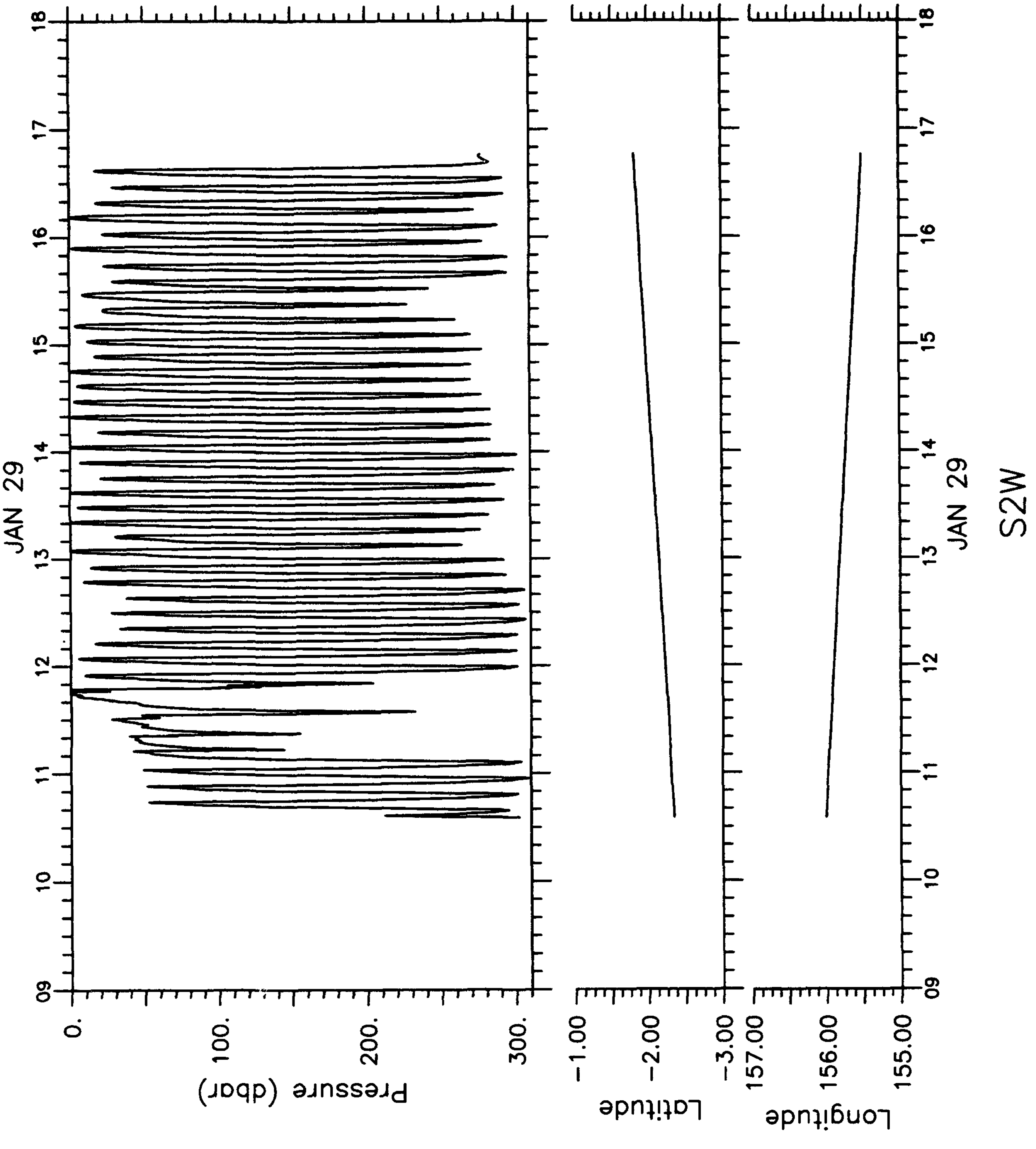
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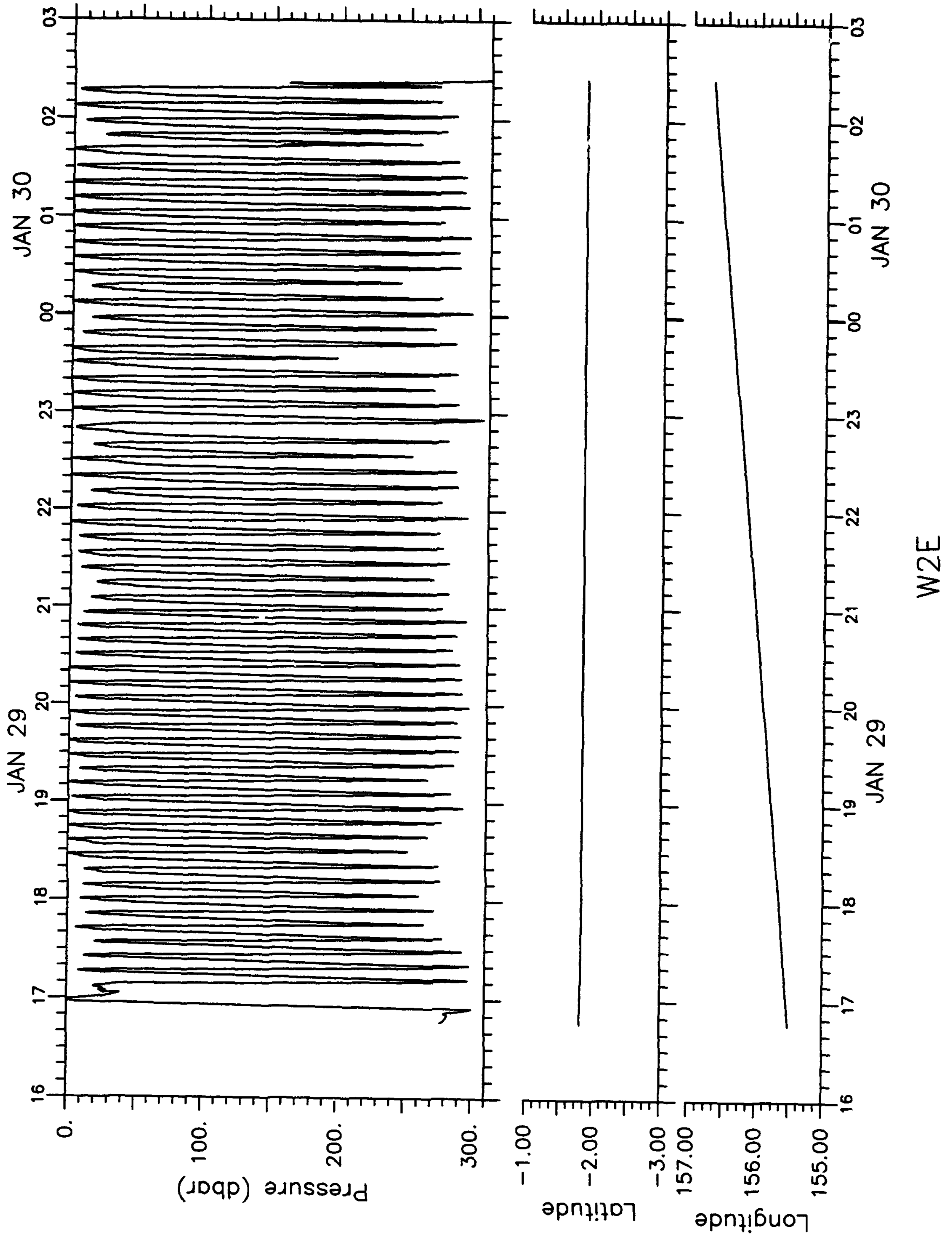
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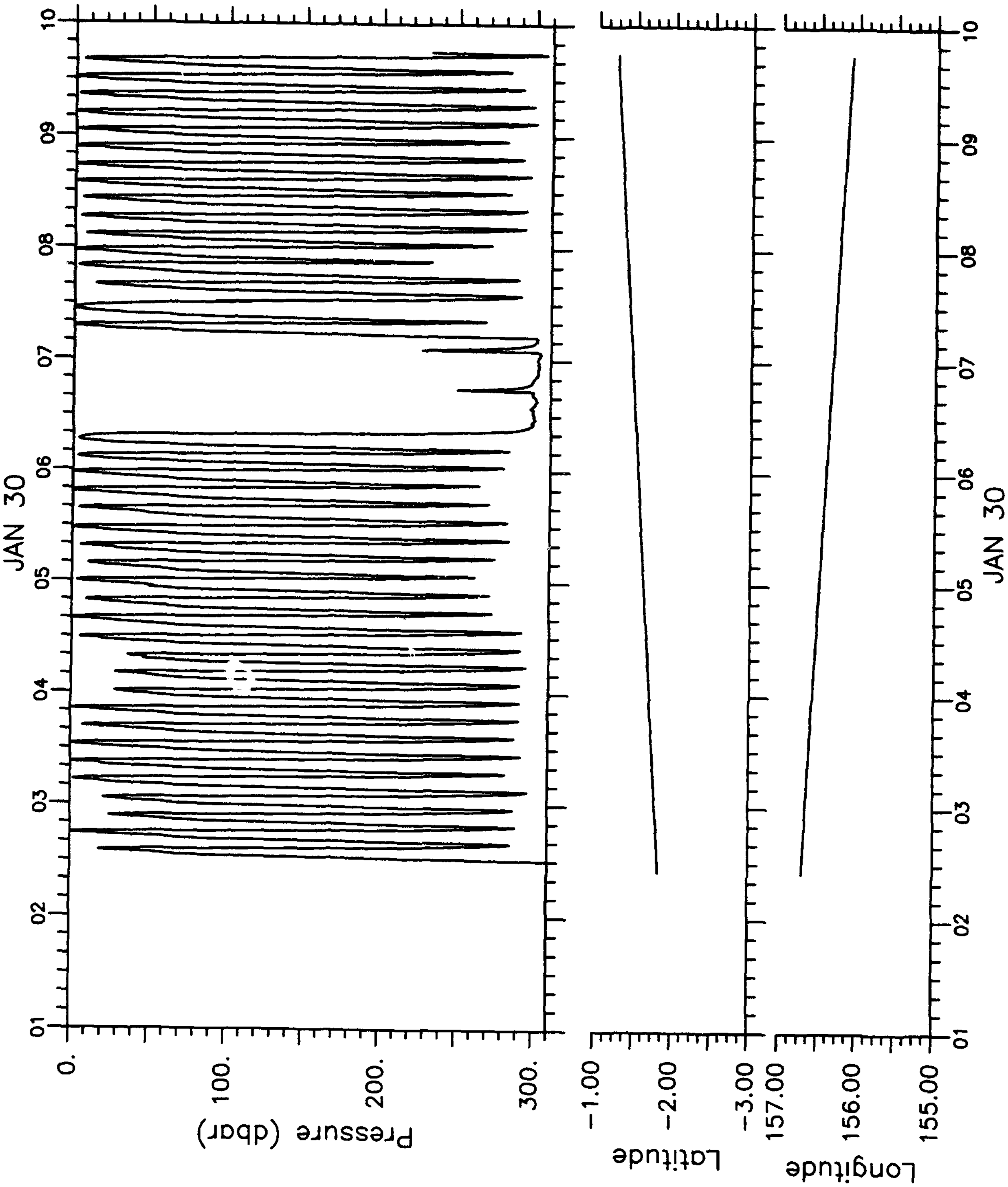

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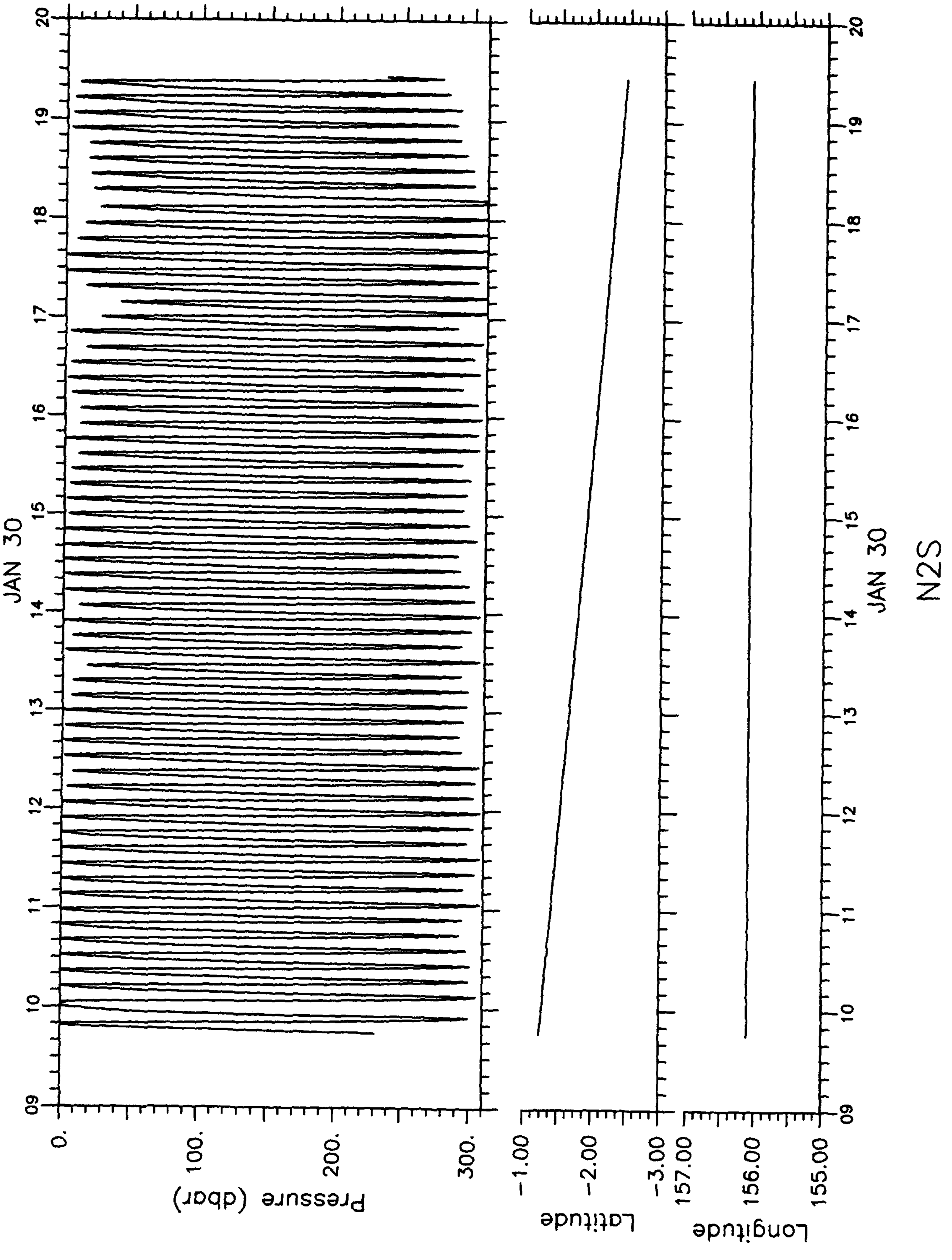
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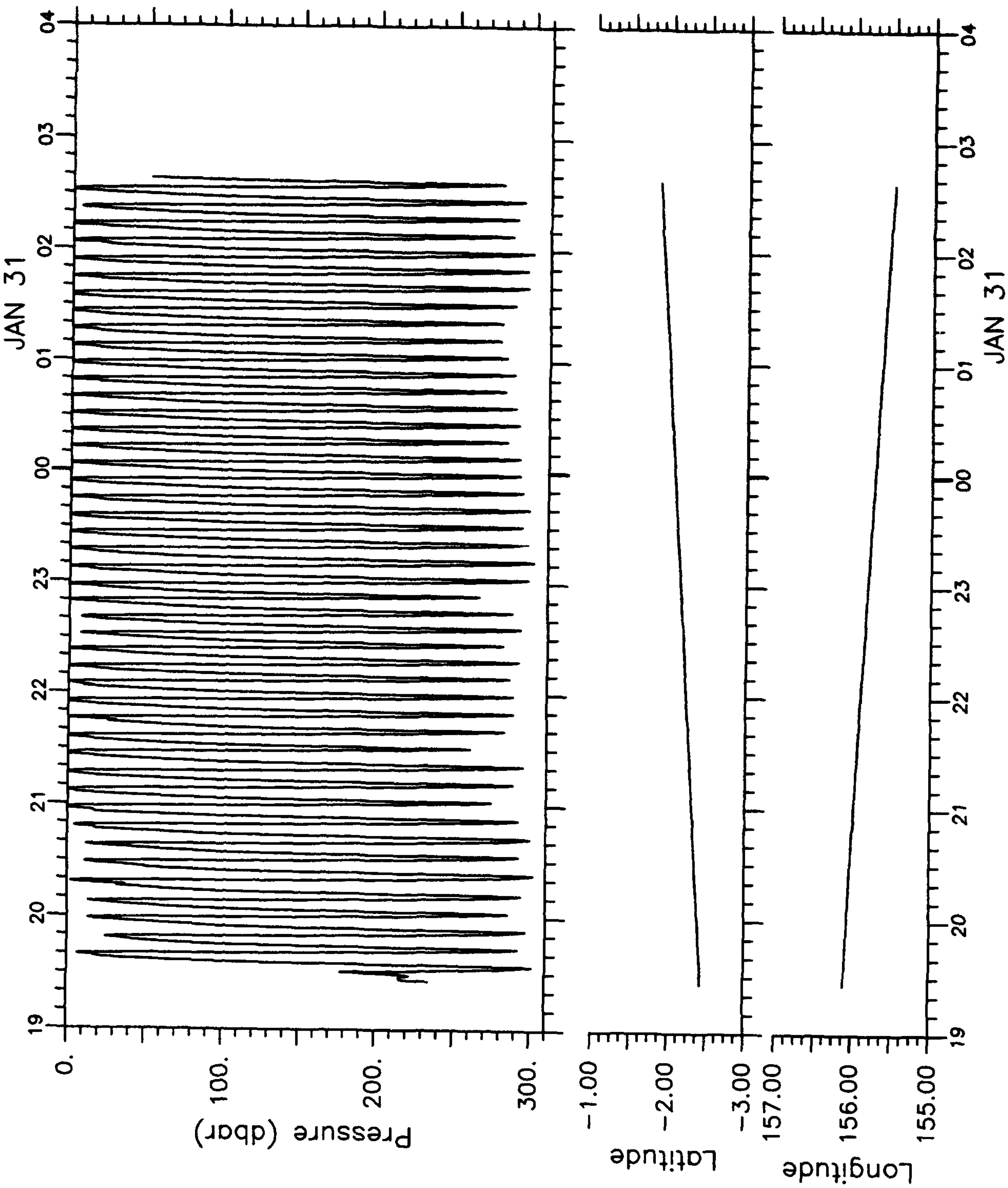
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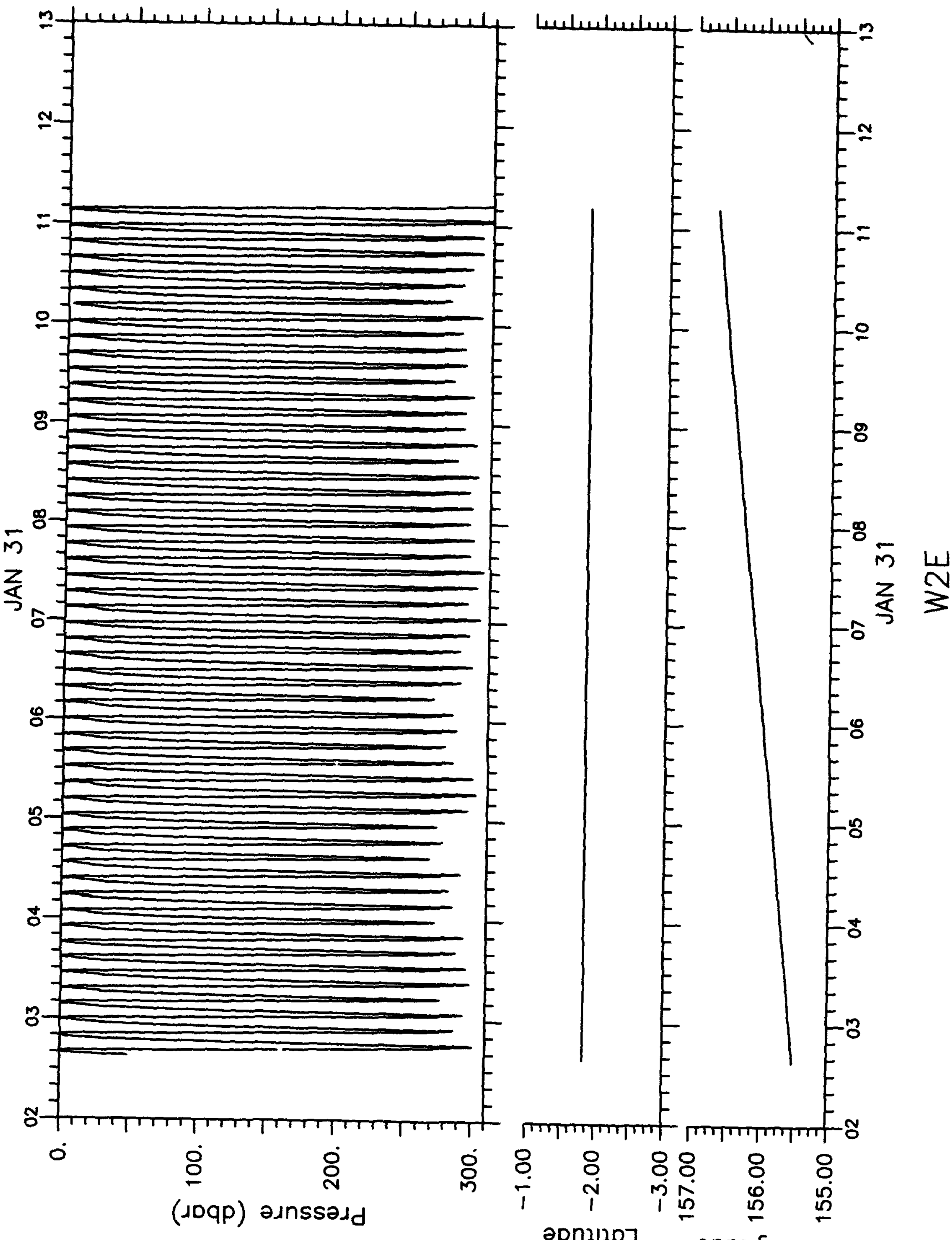
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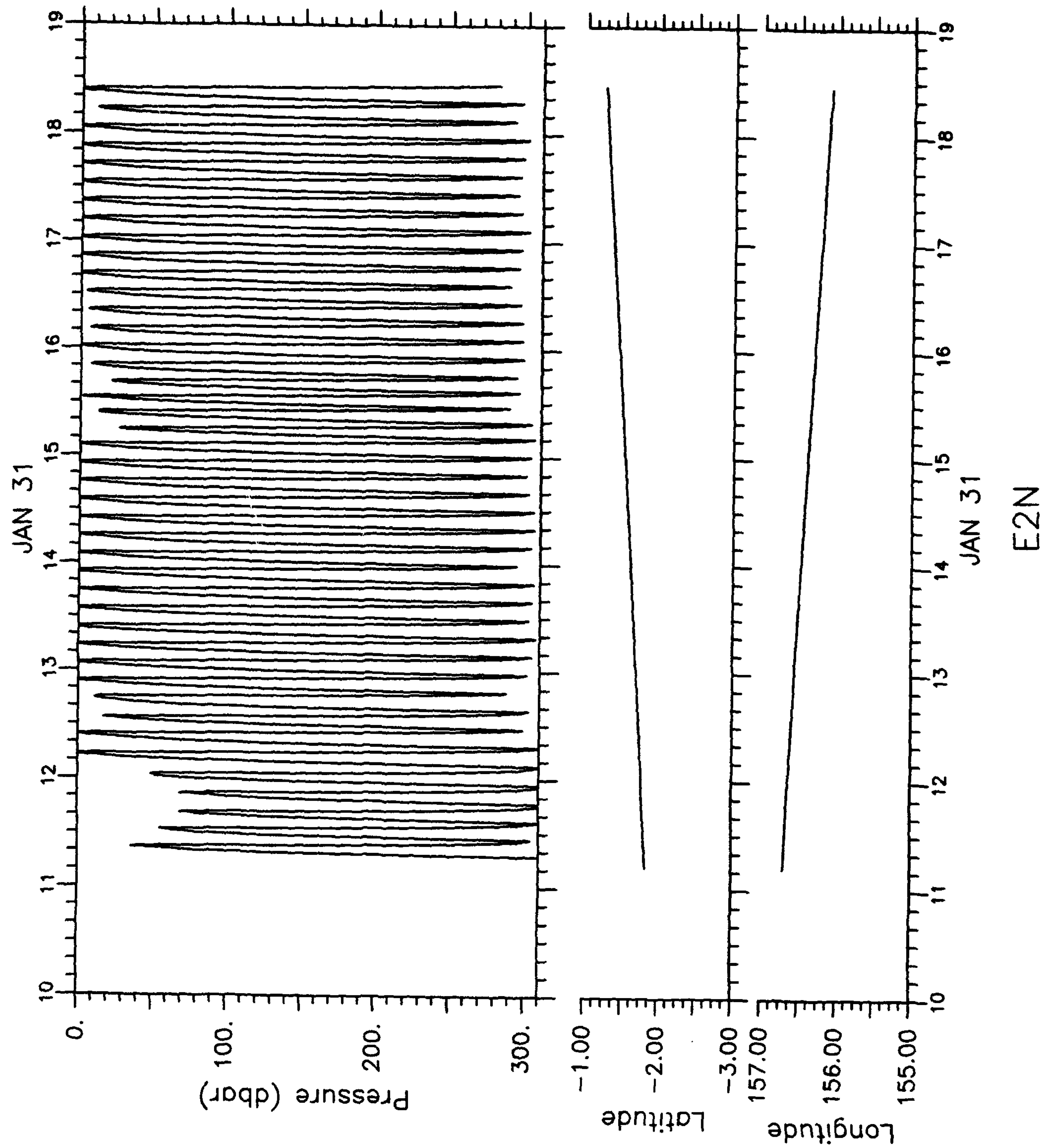
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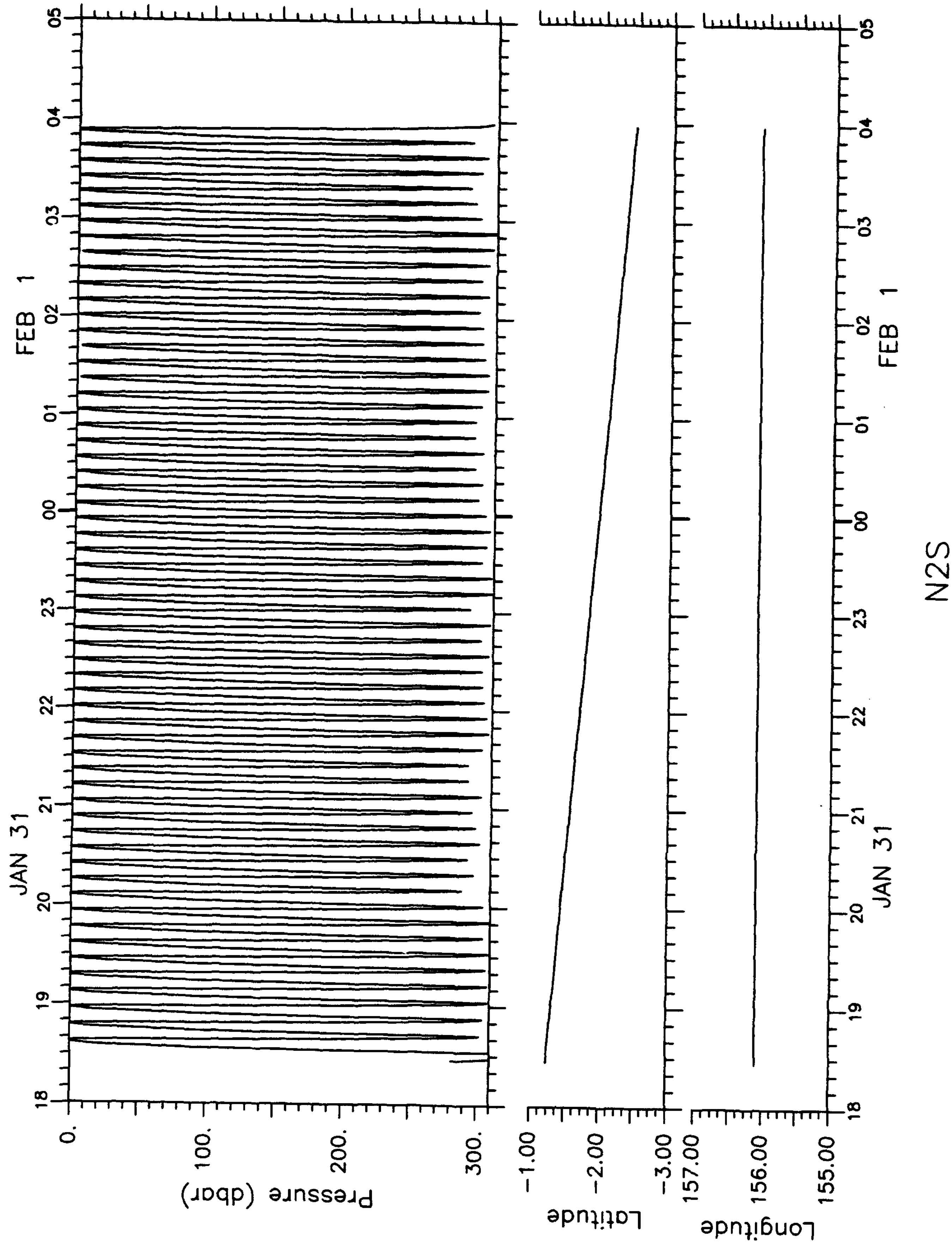
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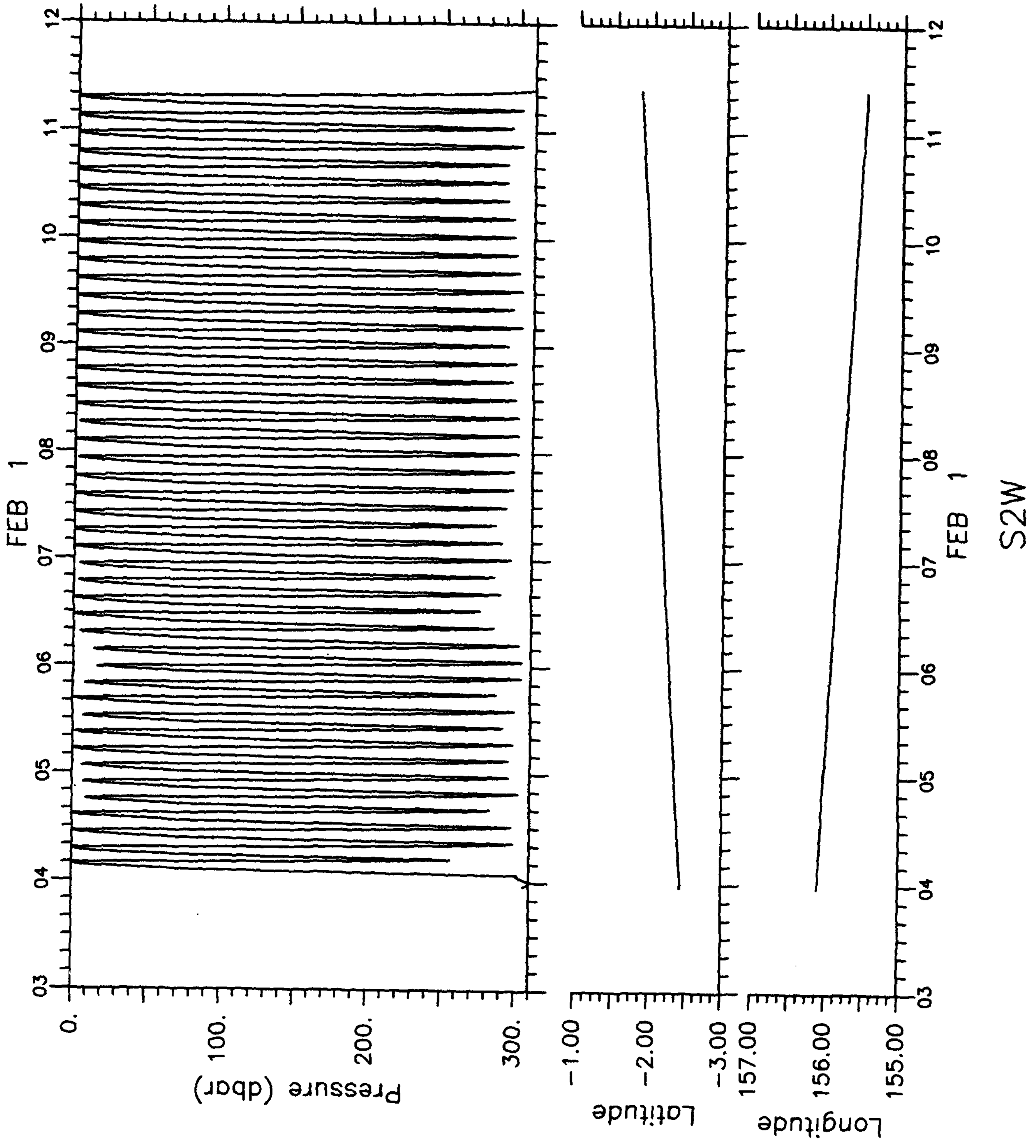
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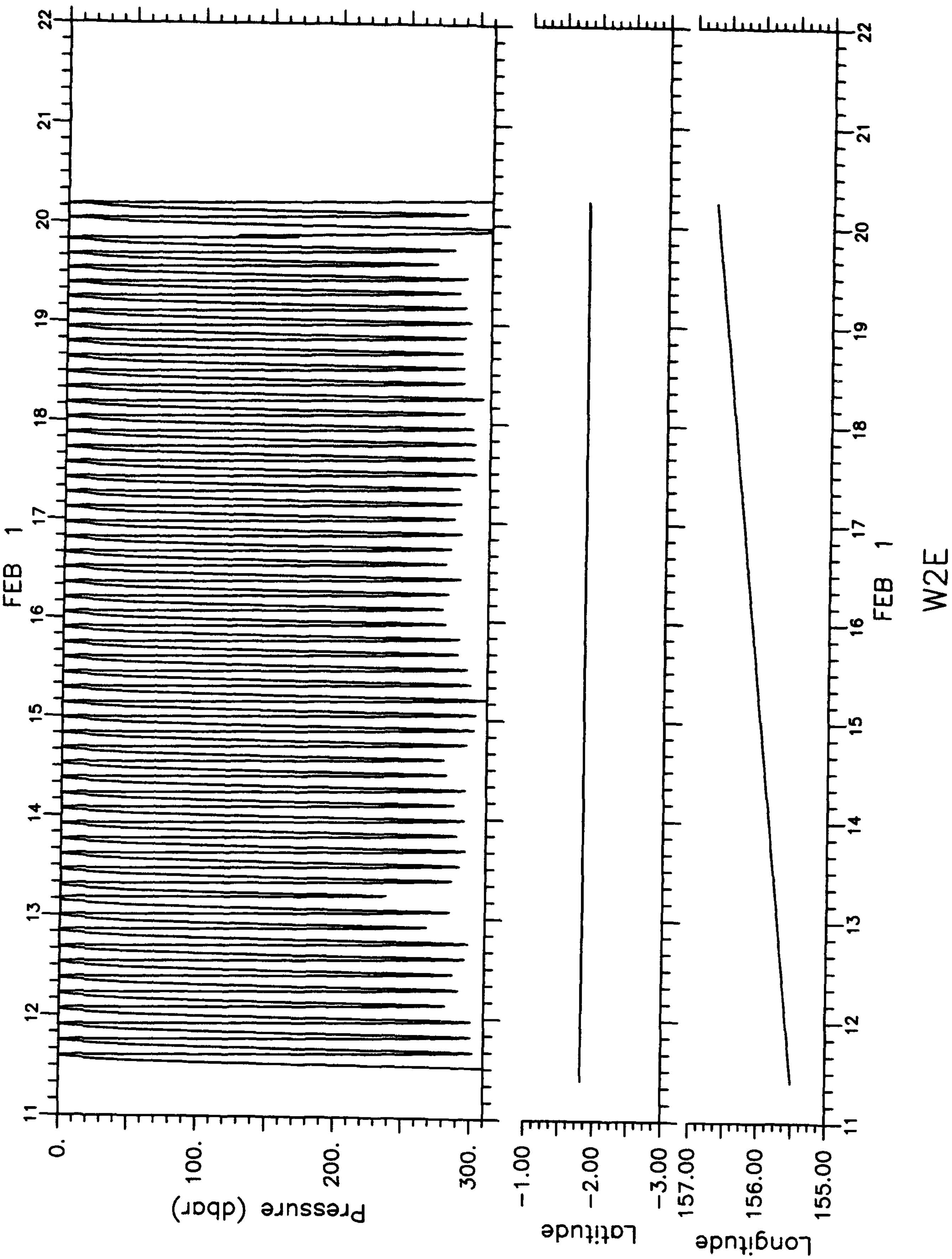
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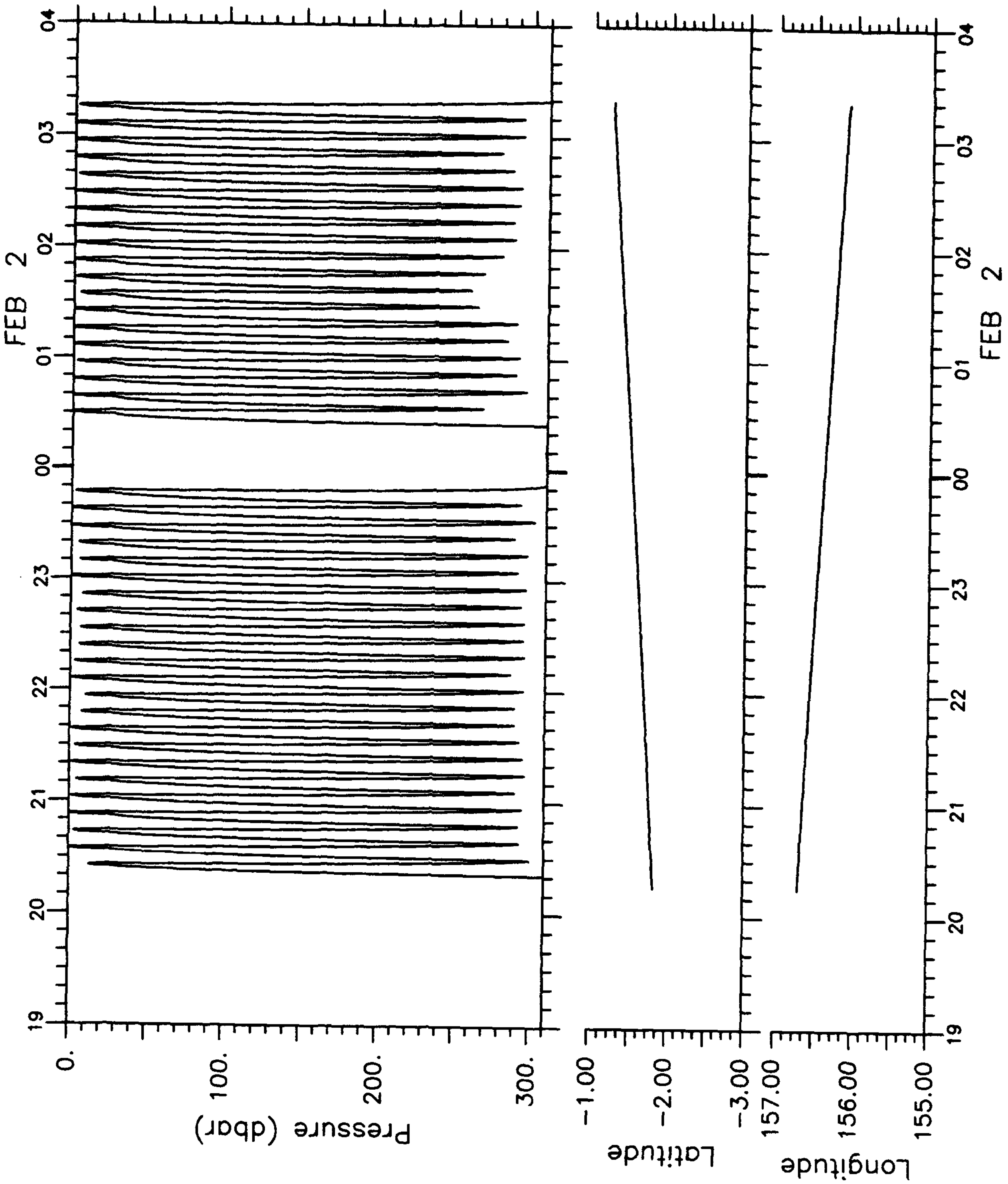
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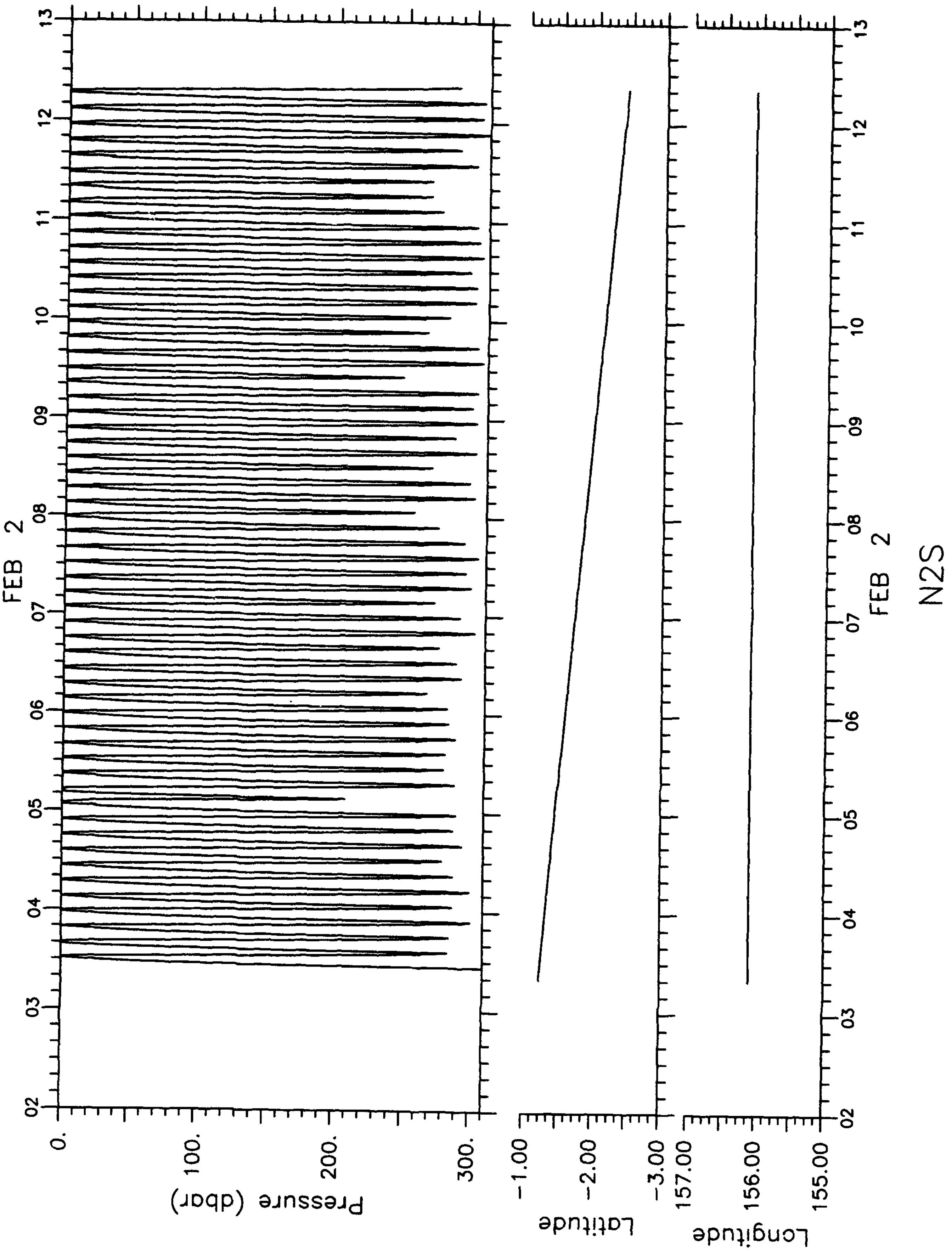
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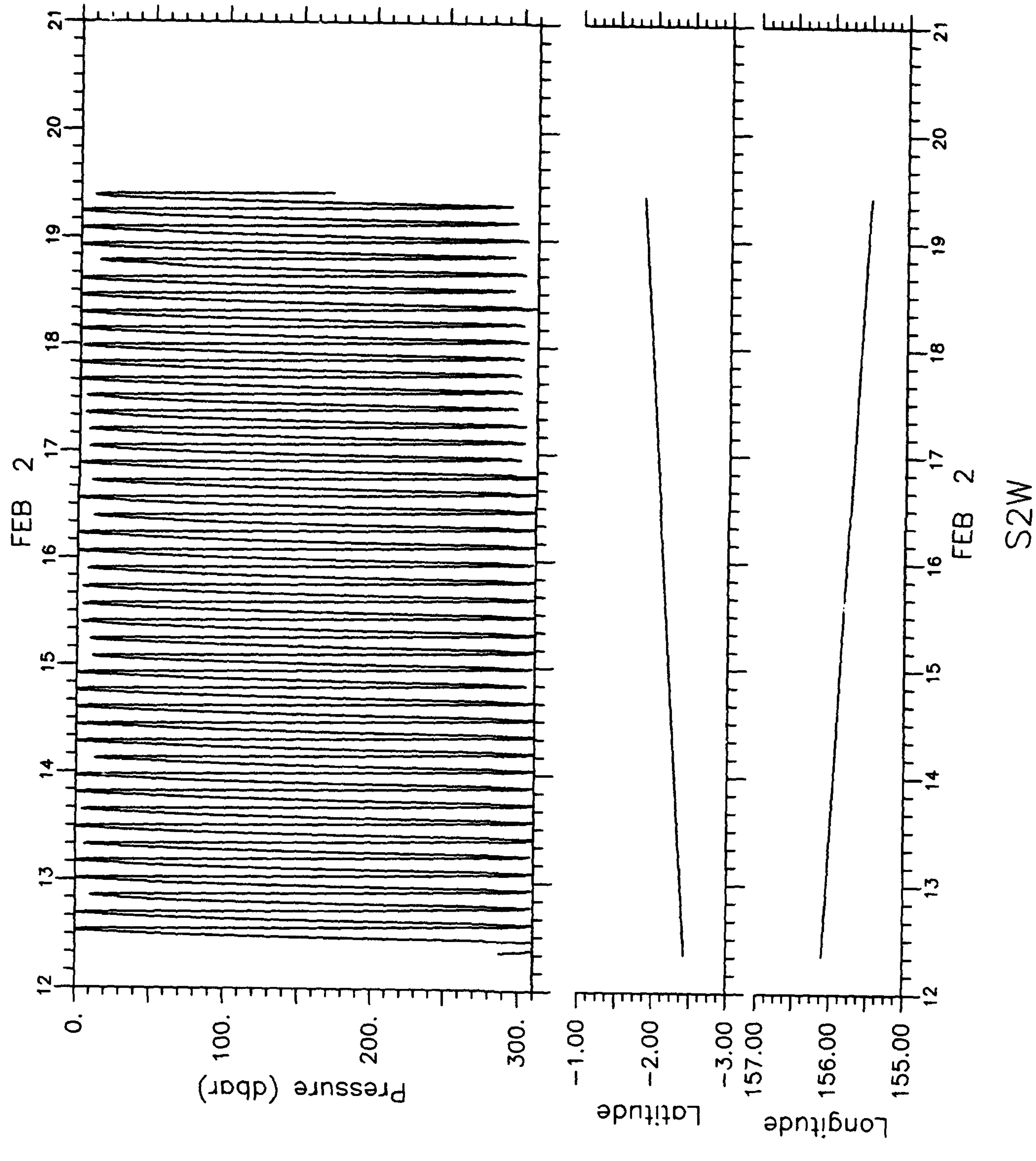
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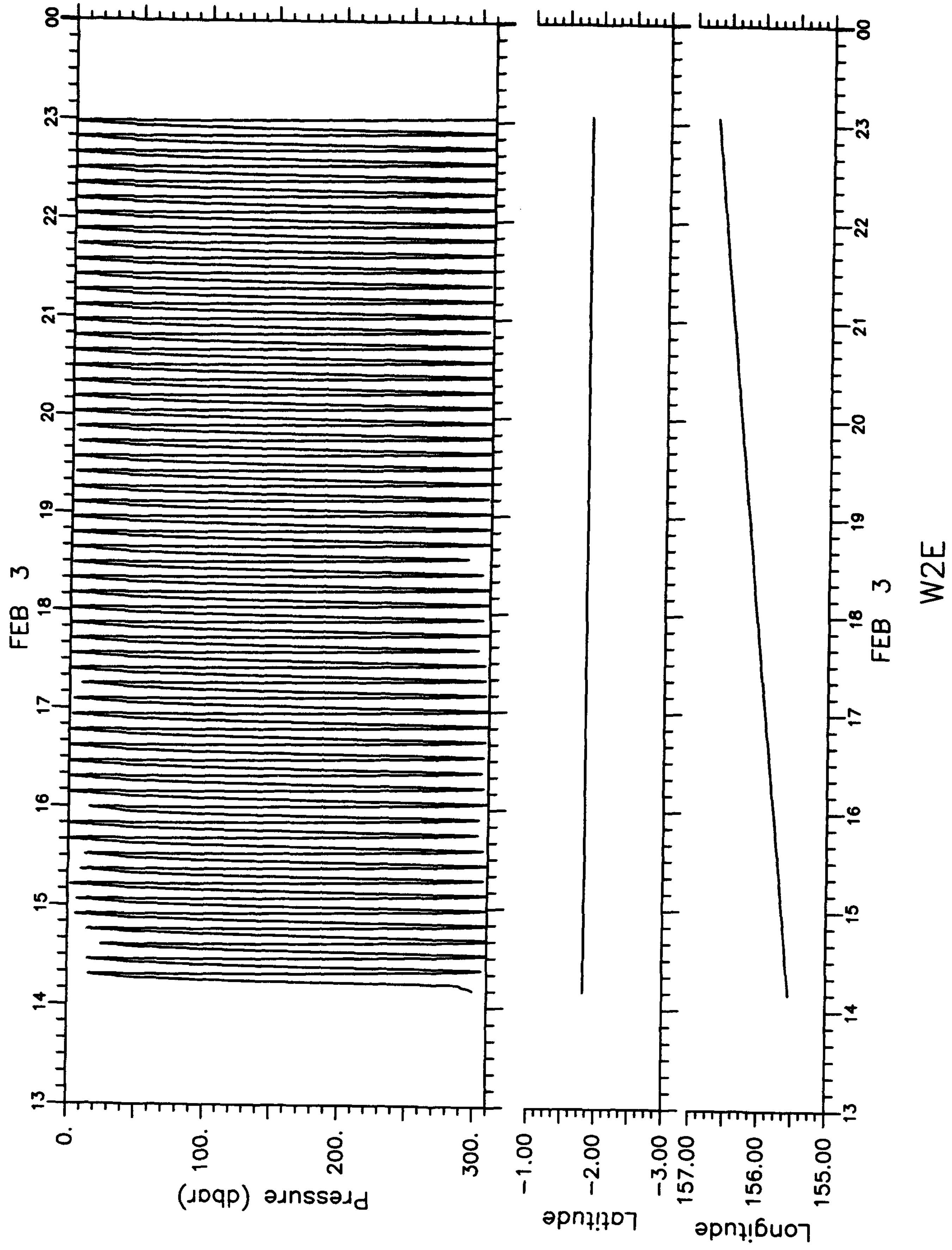
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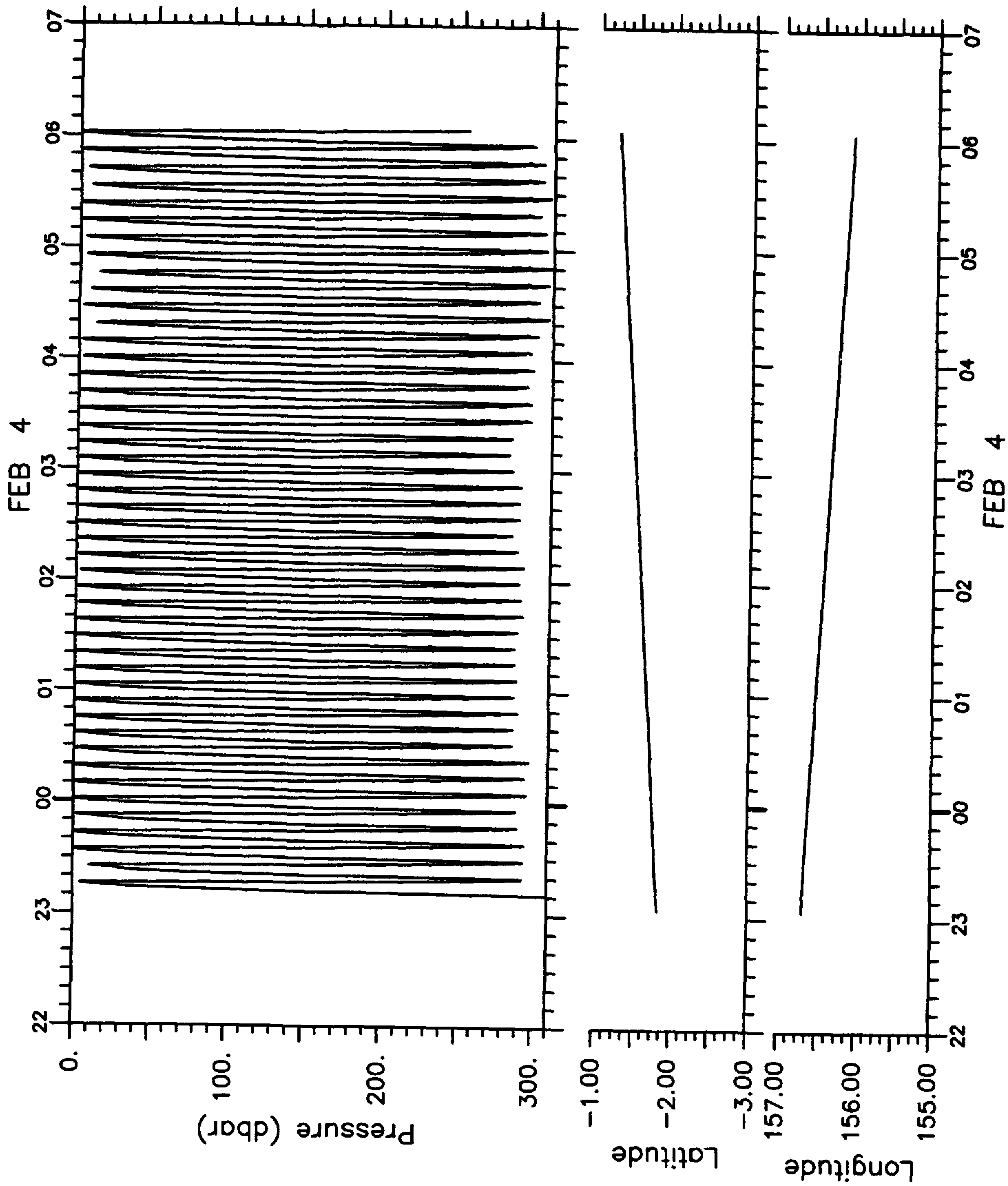
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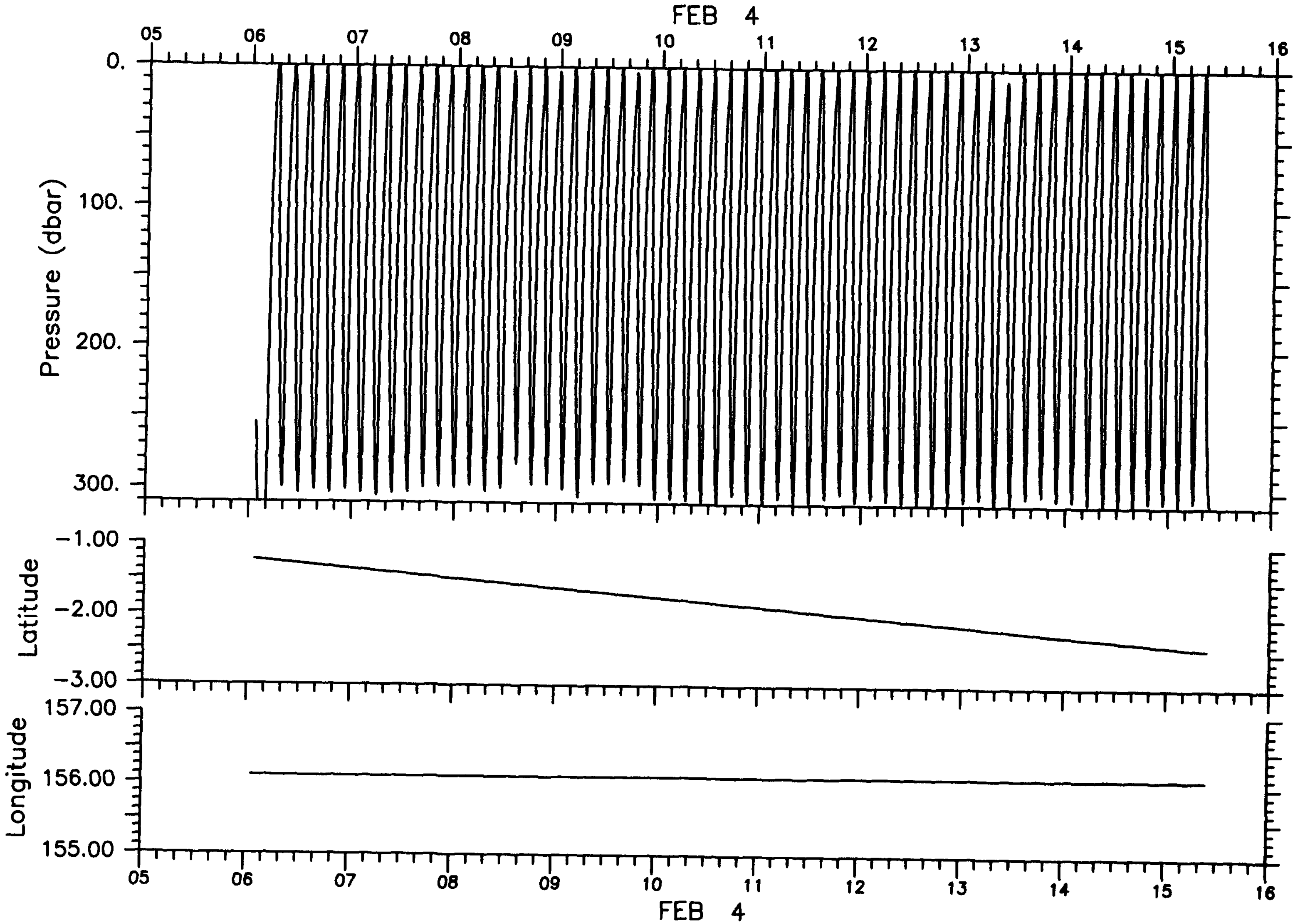
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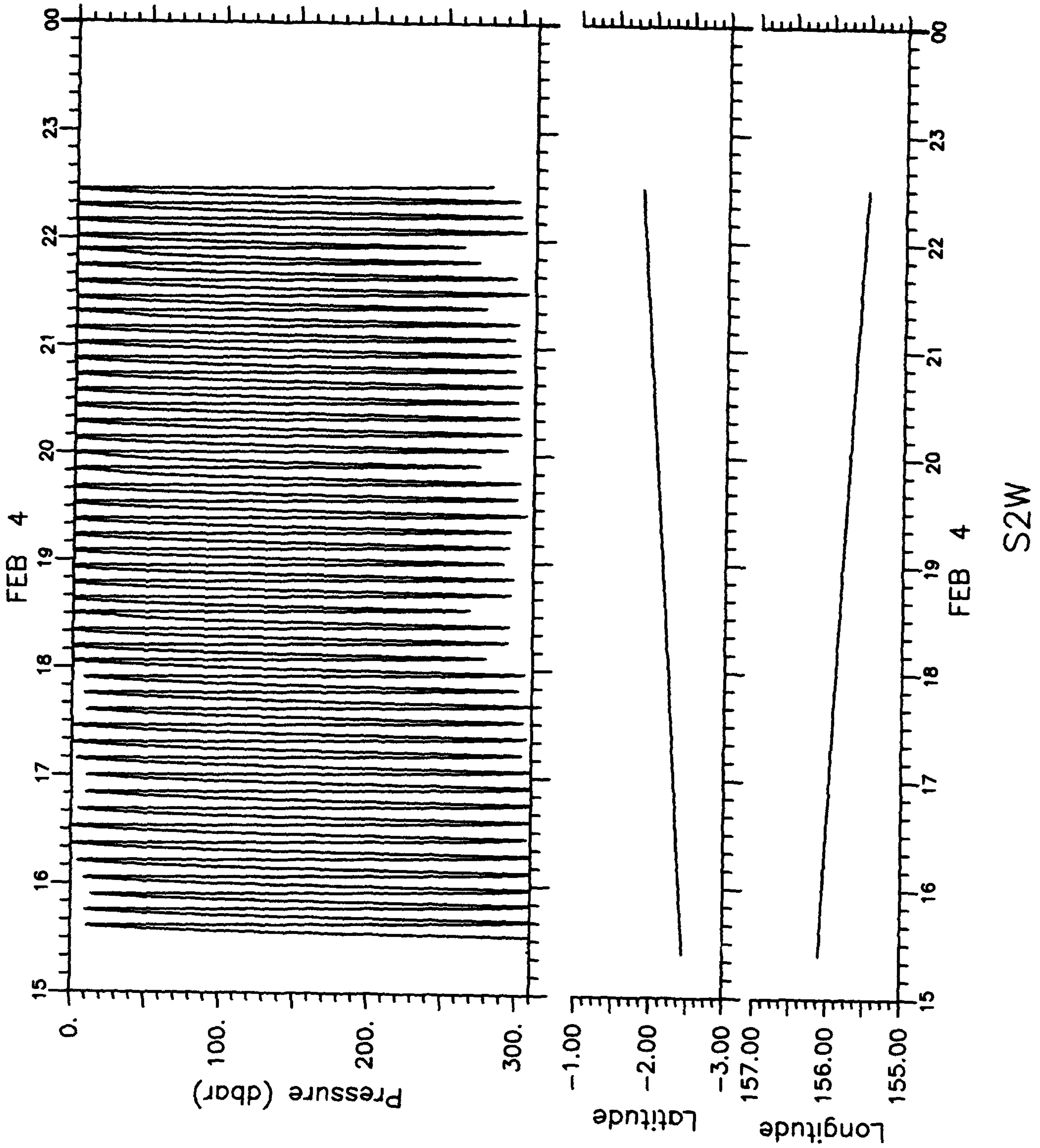
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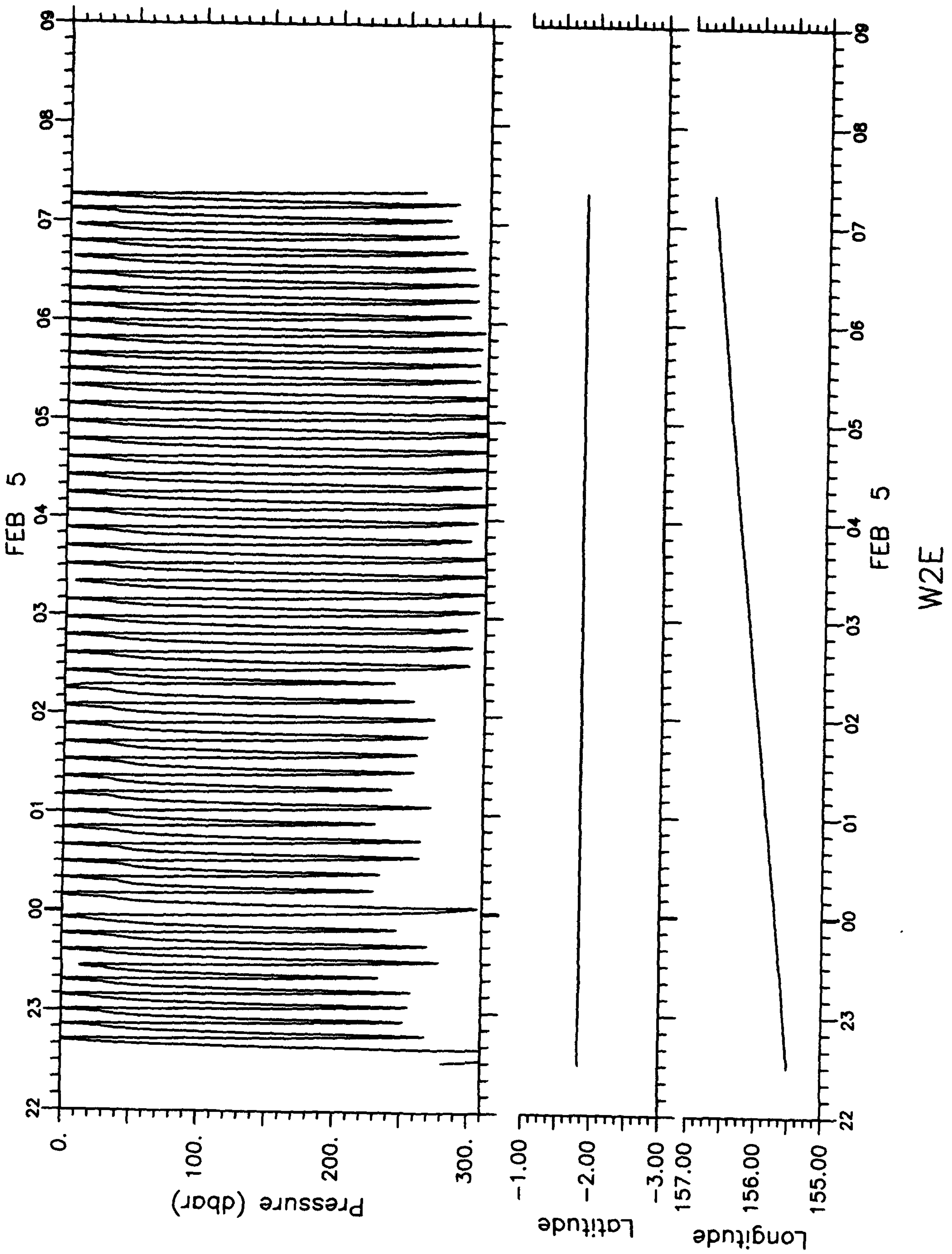
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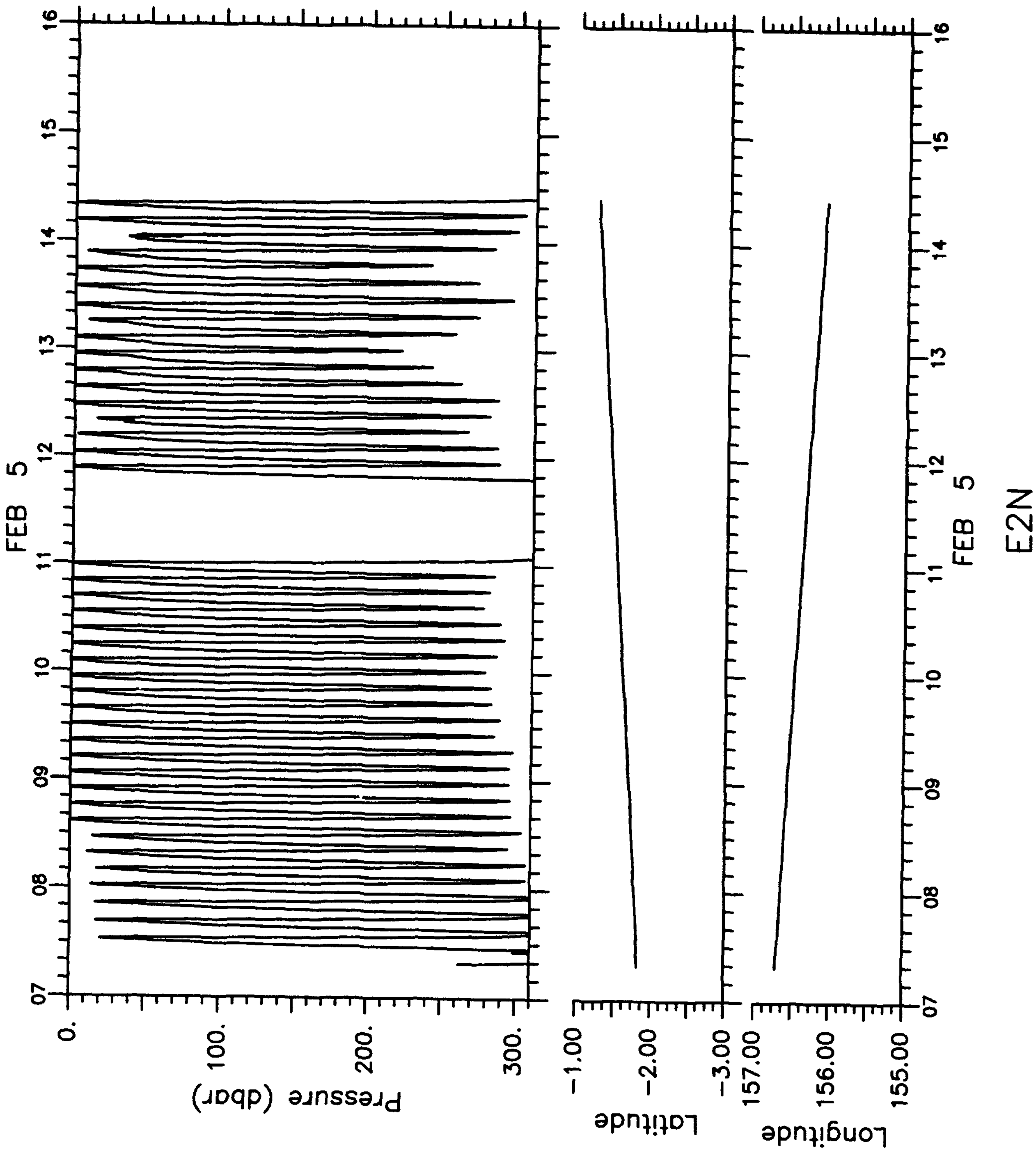
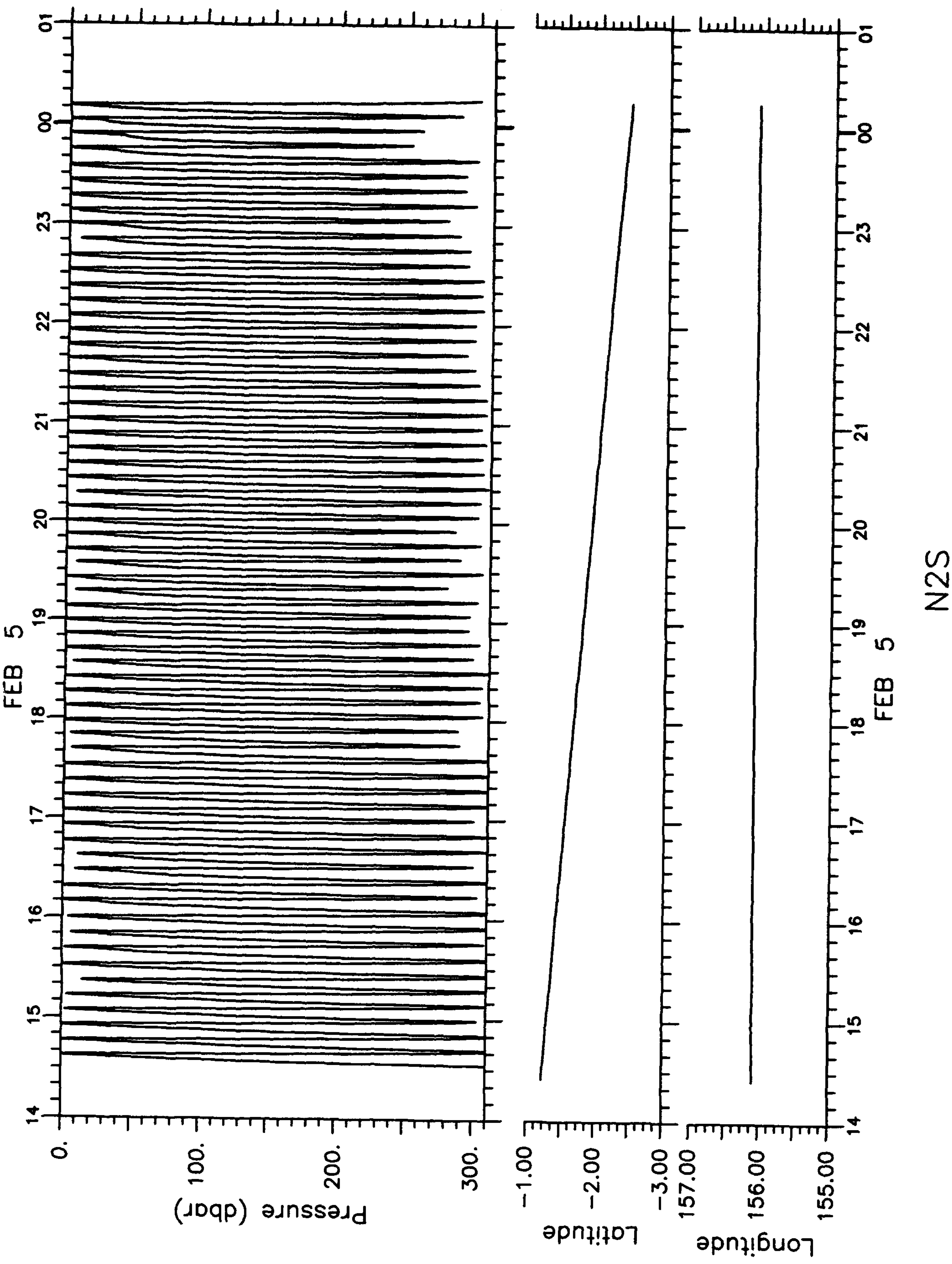

Pressure (dbar)
Latitude
Longitude
FEB 5
E2N



14
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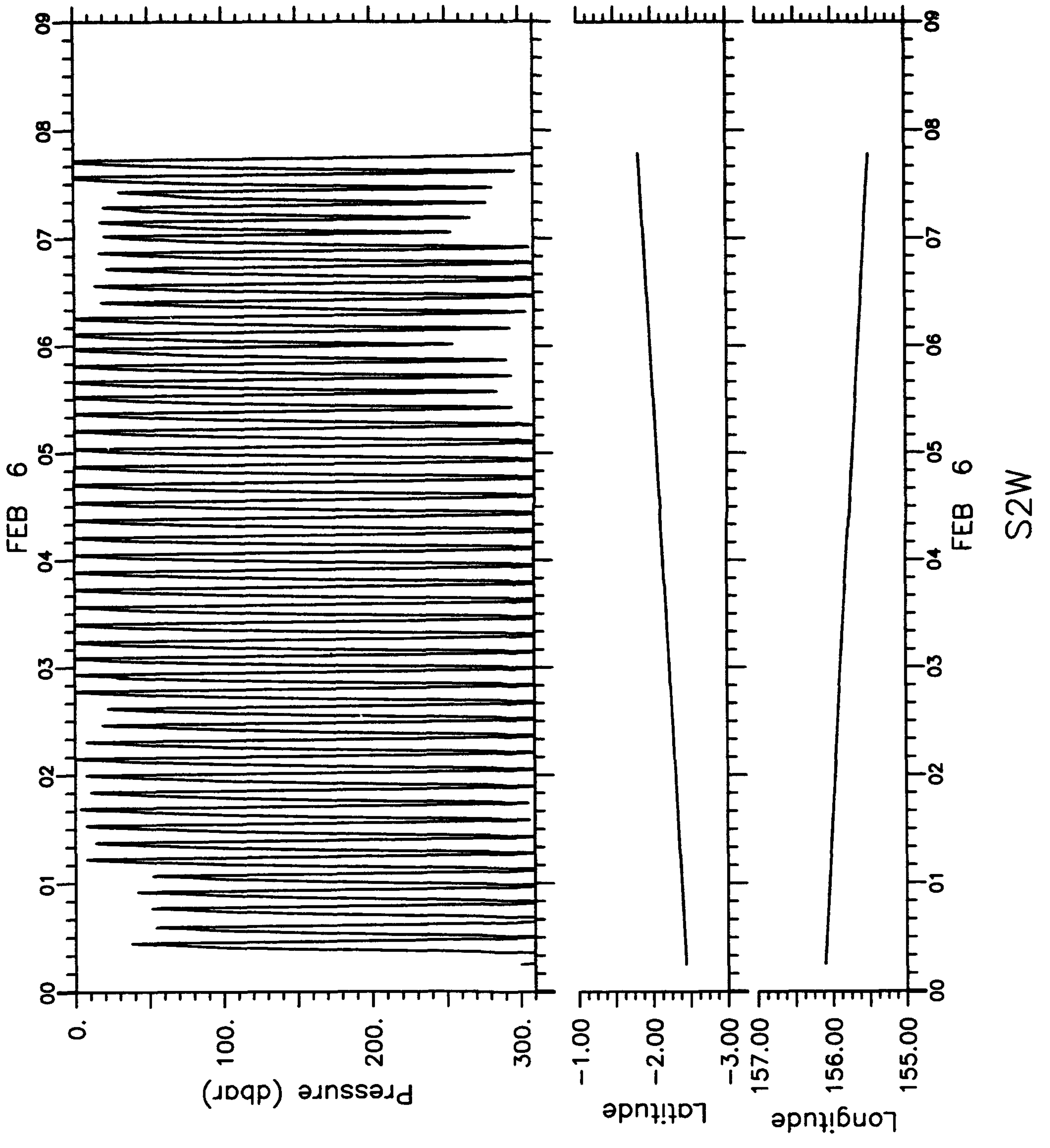
23
00
01
FEB 5
0.
100.
200.
300.
Pressure (dbar)
-1.00
-2.00
-3.00
Latitude
157.00
156.00
155.00
Longitude
N2S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Latitude
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Longitude
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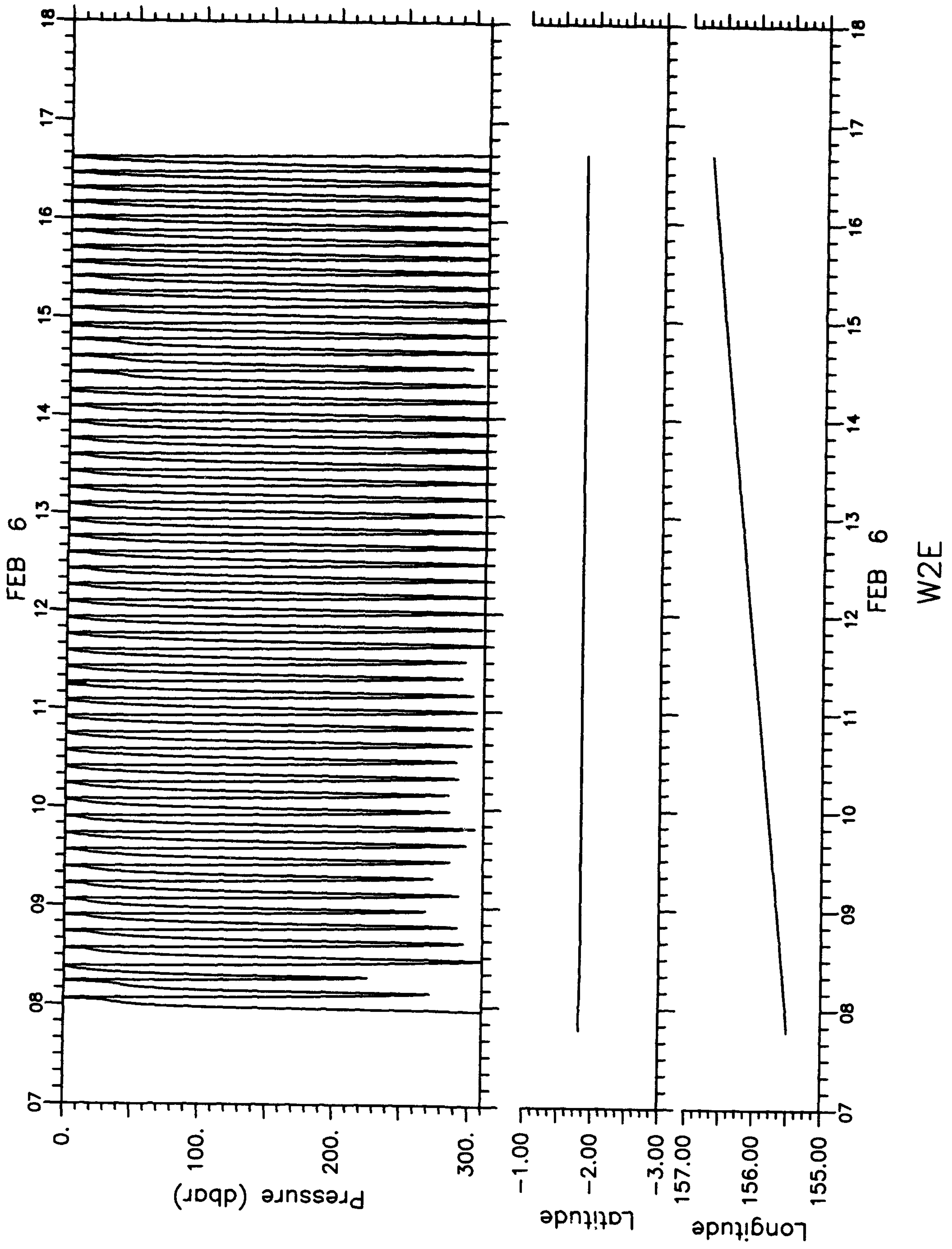

Pressure (dbar)
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100.
200.
300.
Latitude
-1.00
-2.00
-3.00
Longitude
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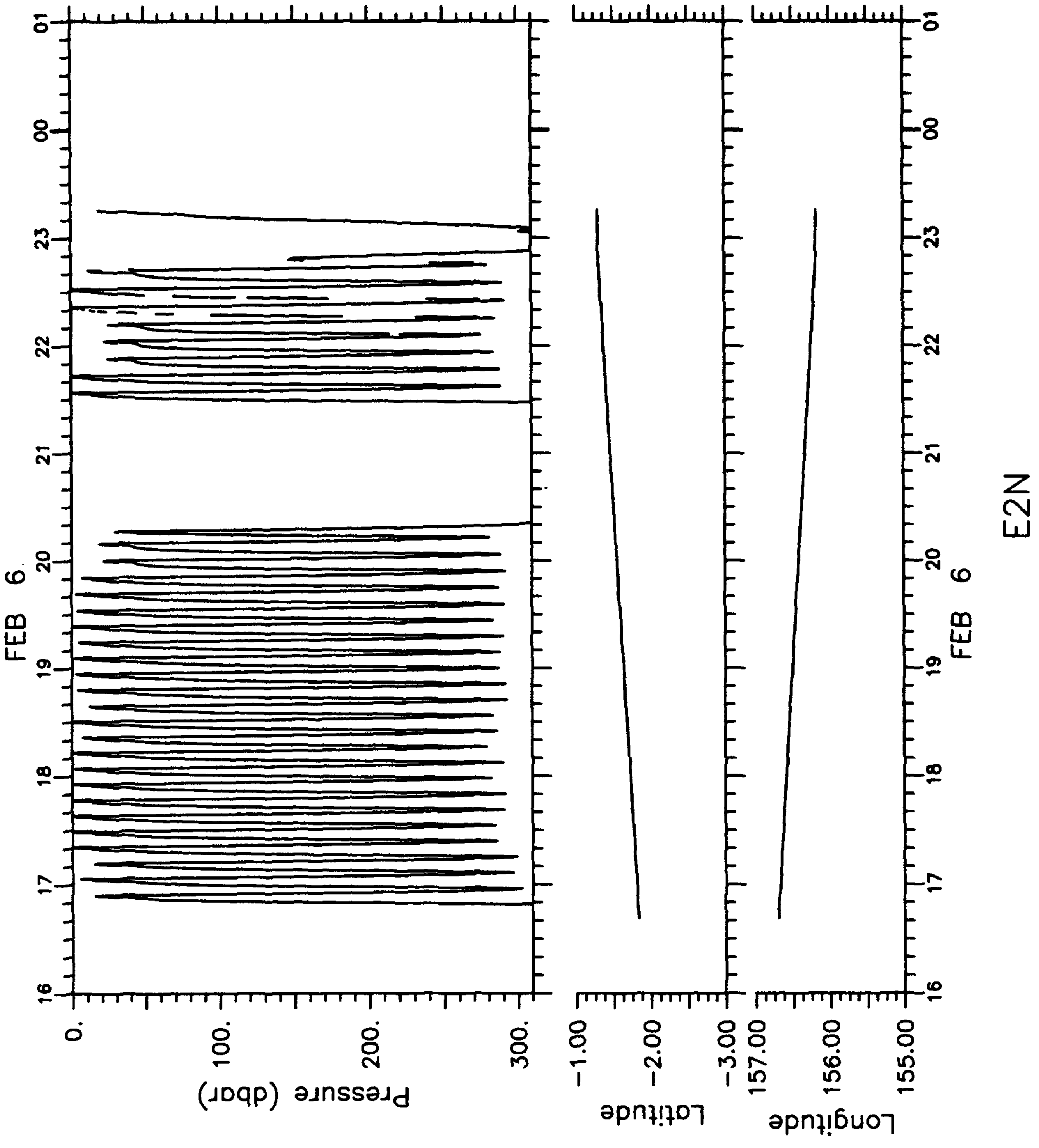
W2E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Longitude
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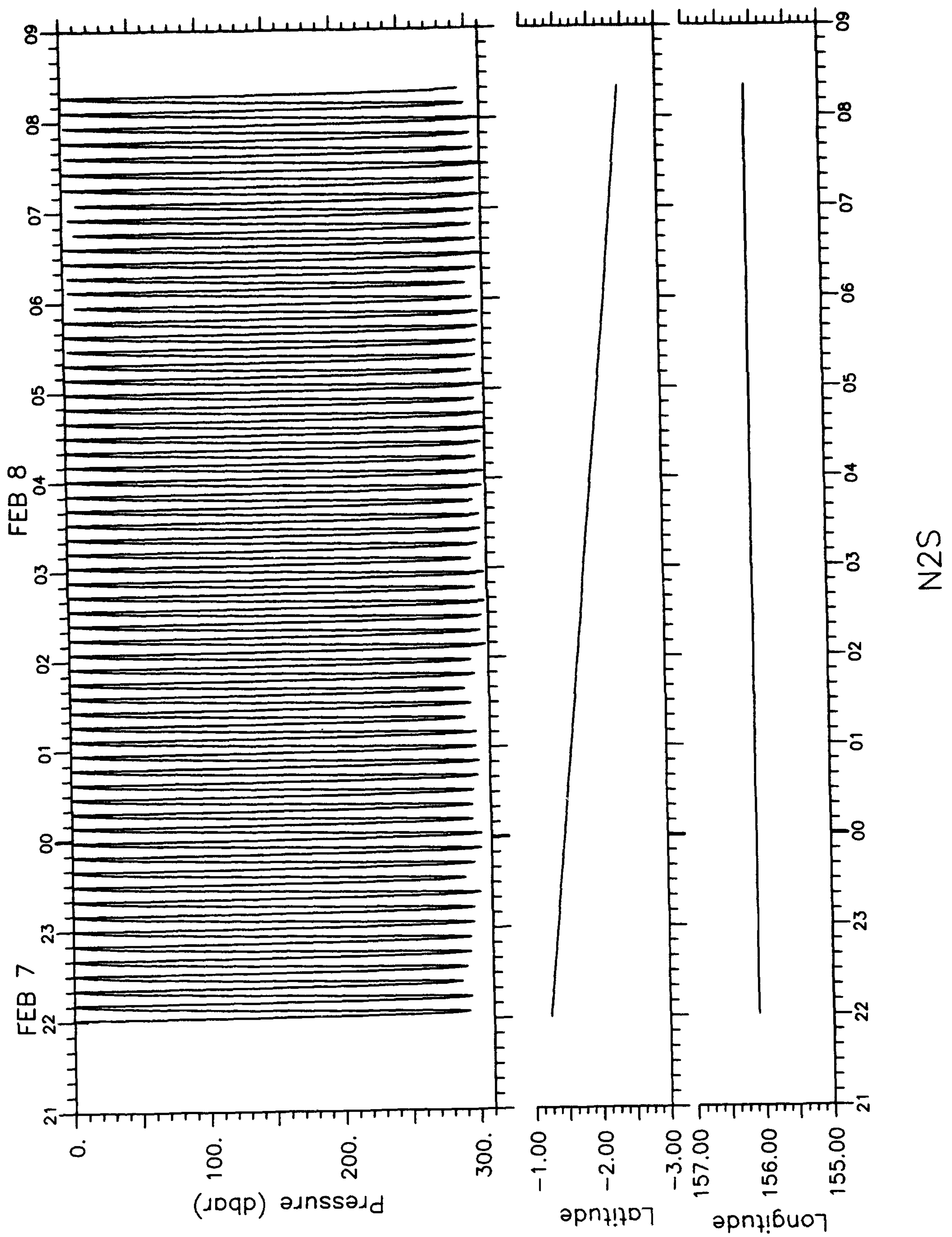
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Longitude
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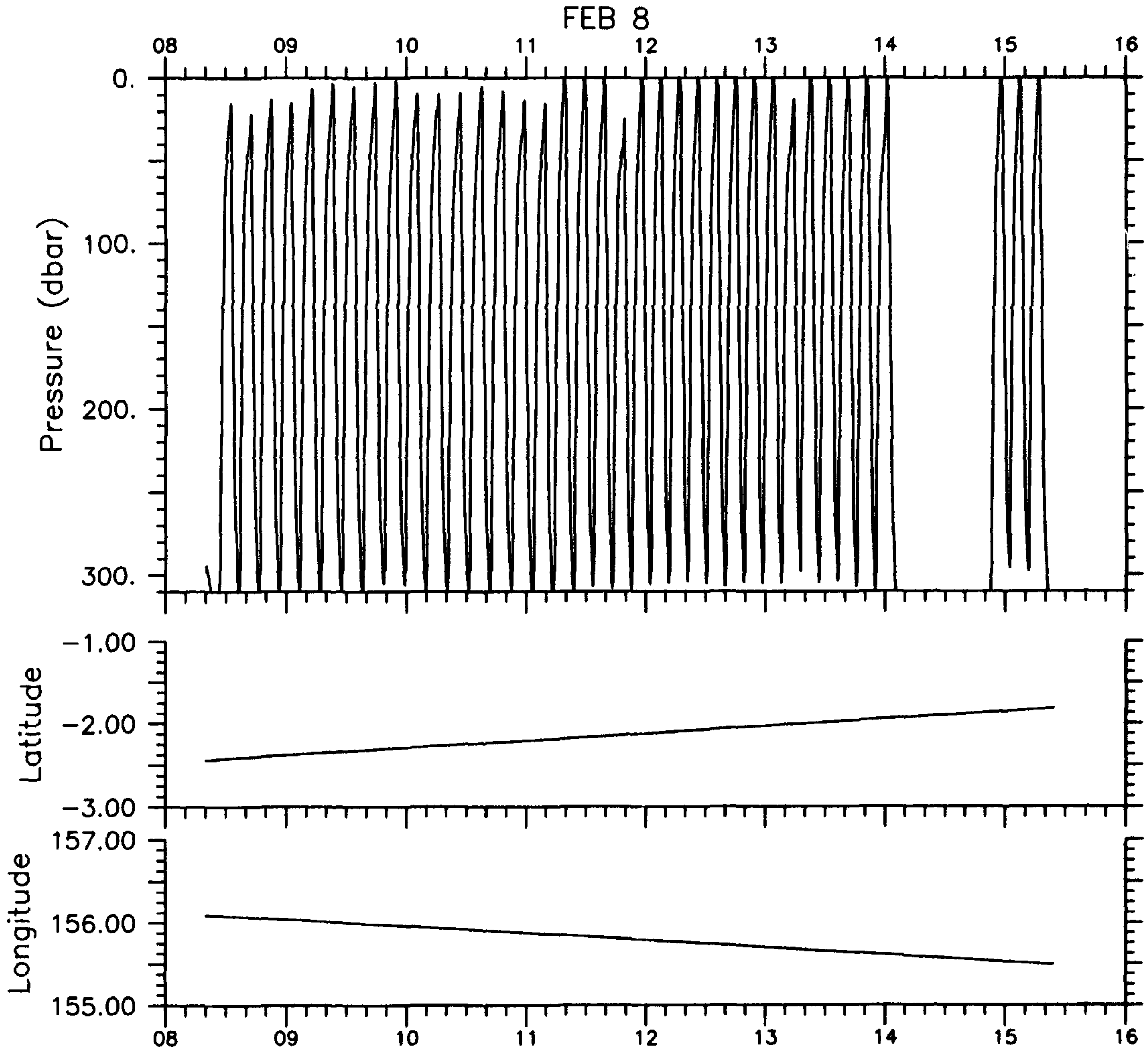
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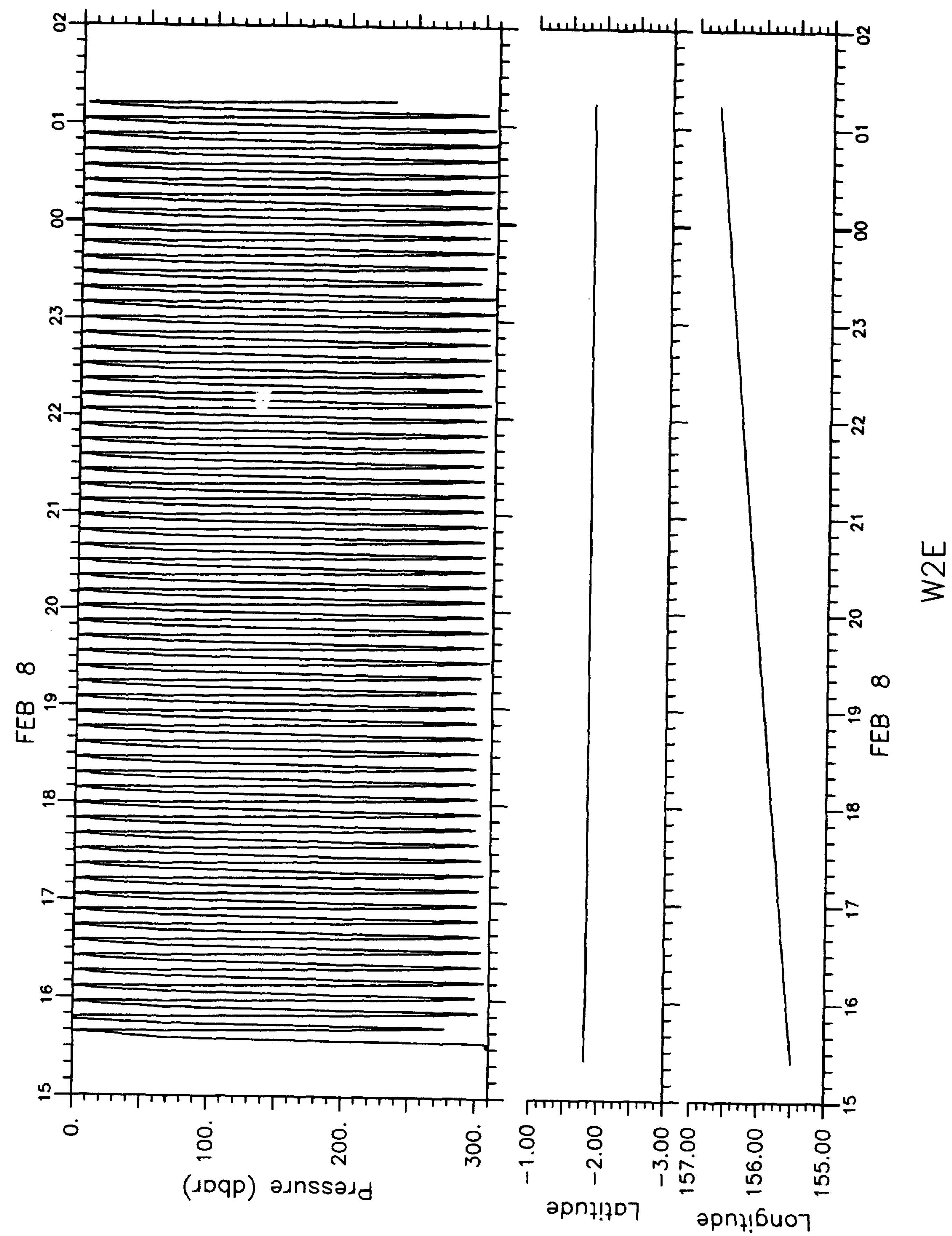
Longitude

S2W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Longitude
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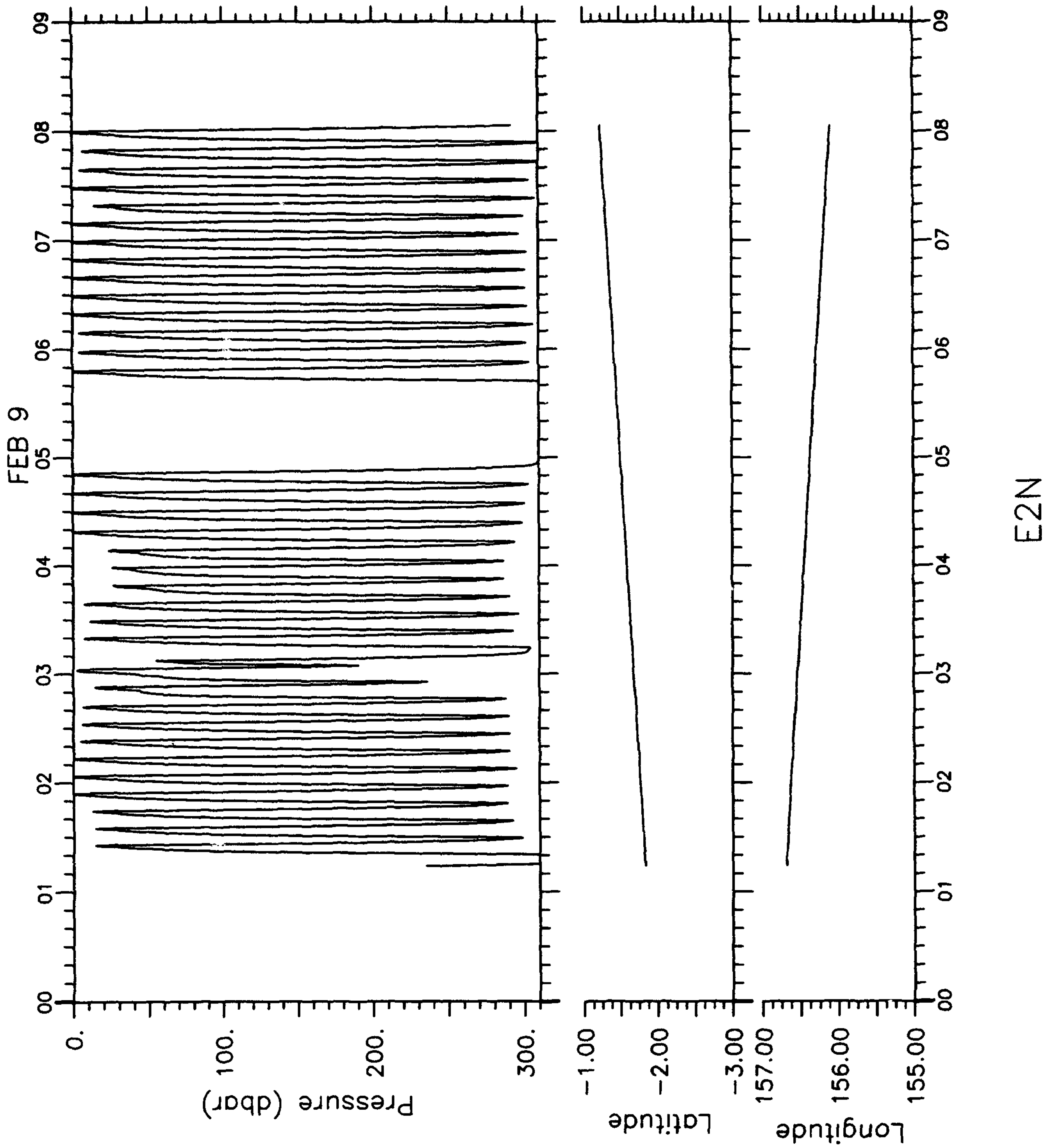
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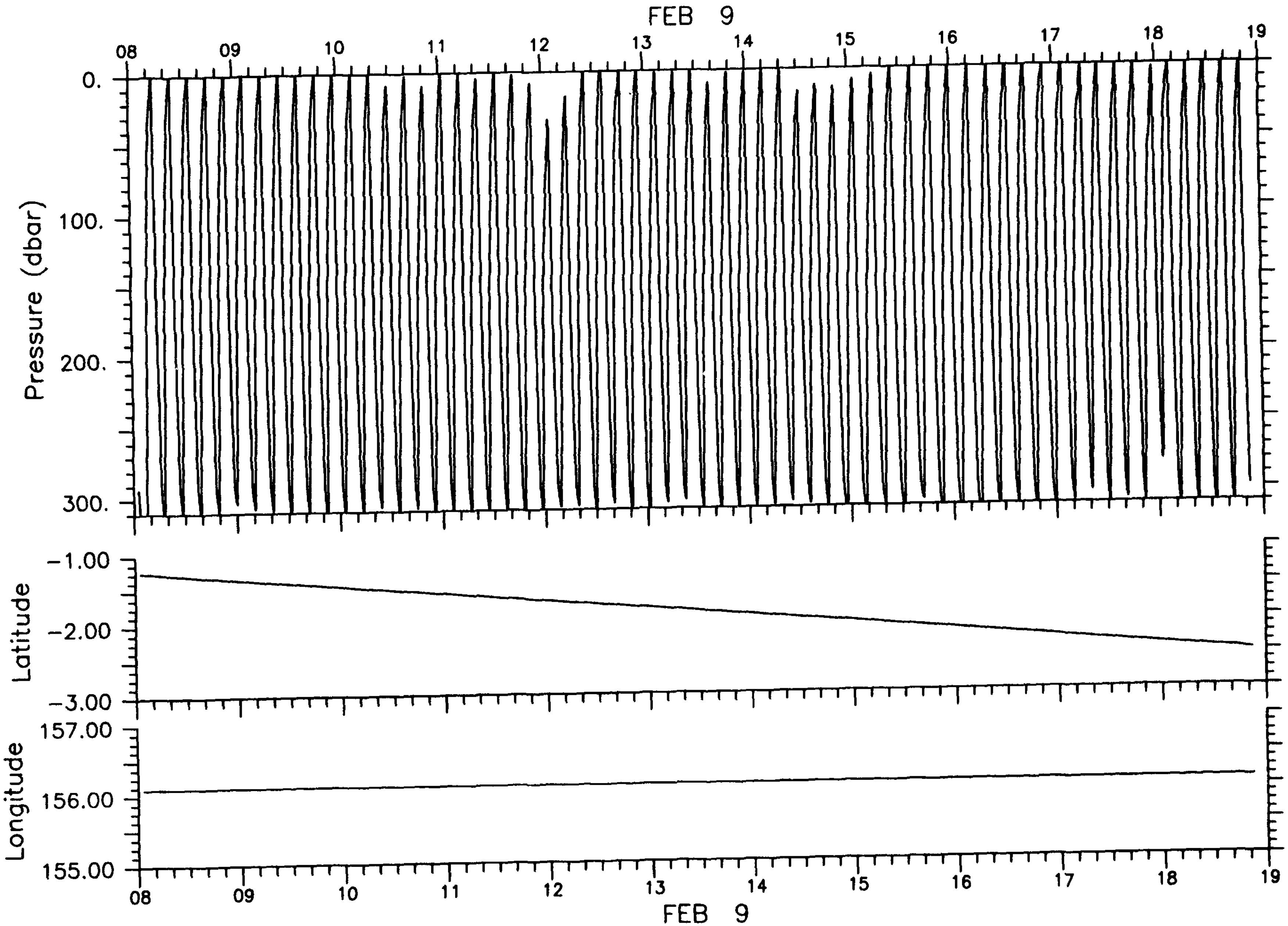
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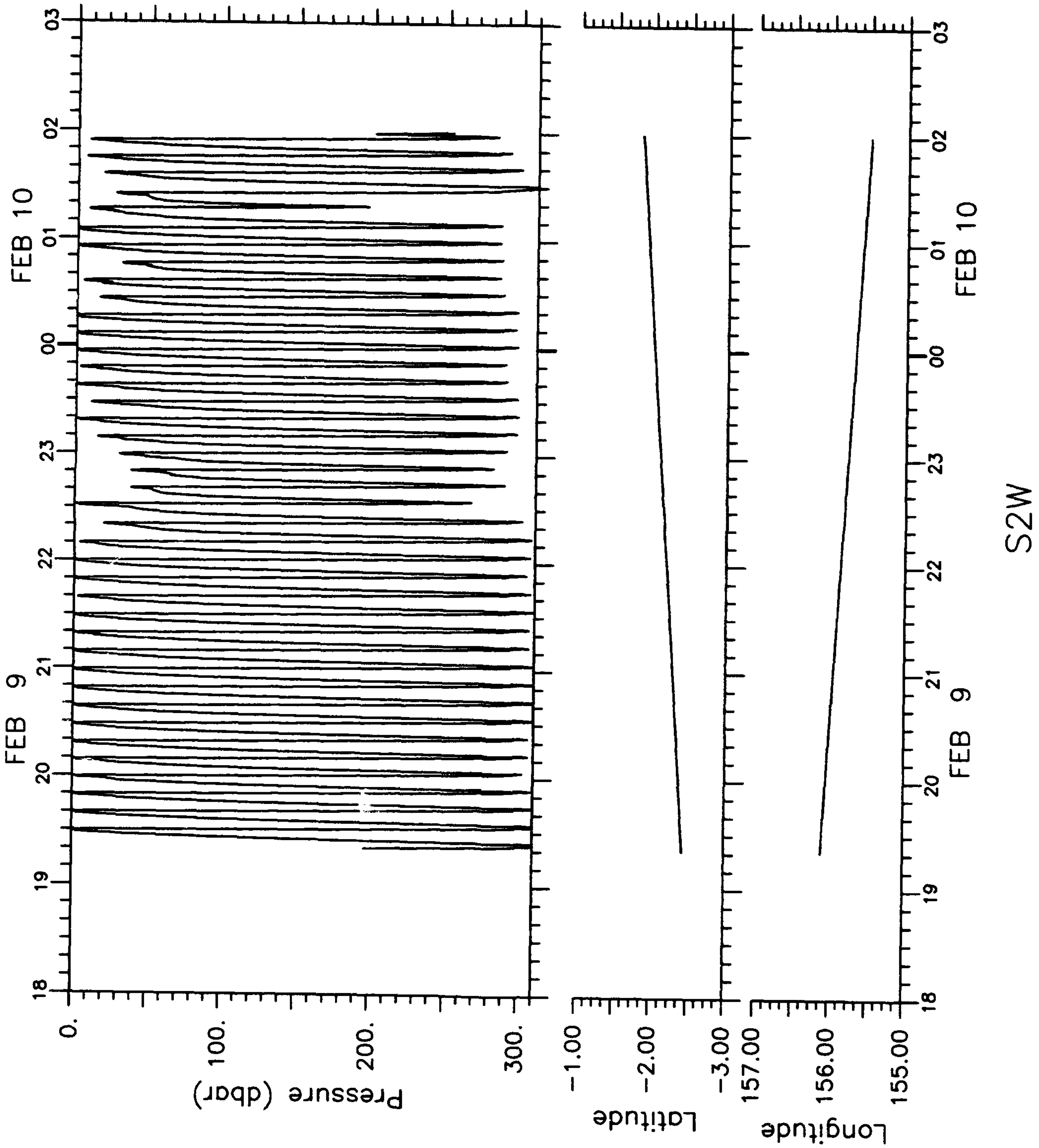

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−3.00
Longitude
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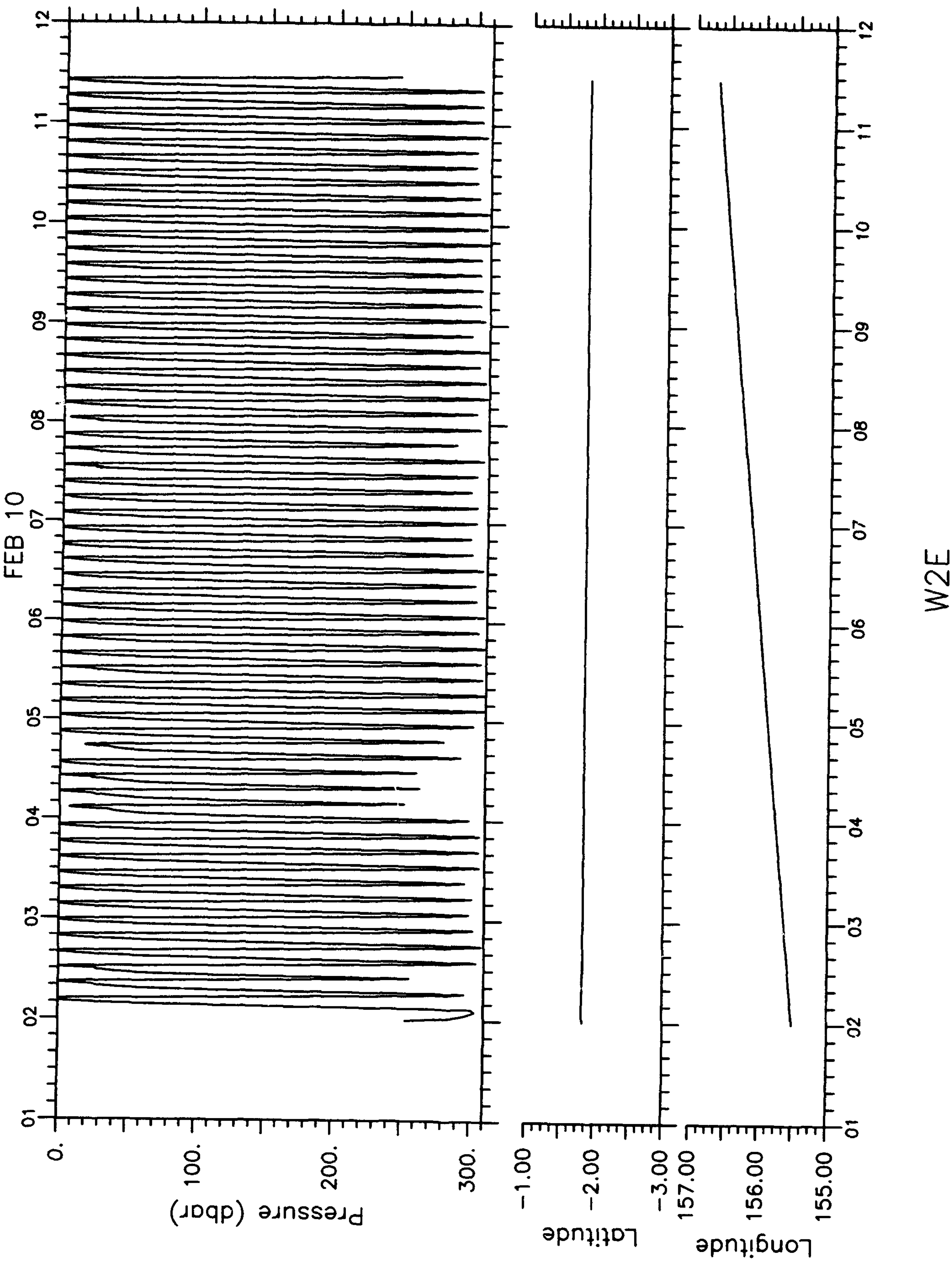
156.00
155.00
S2W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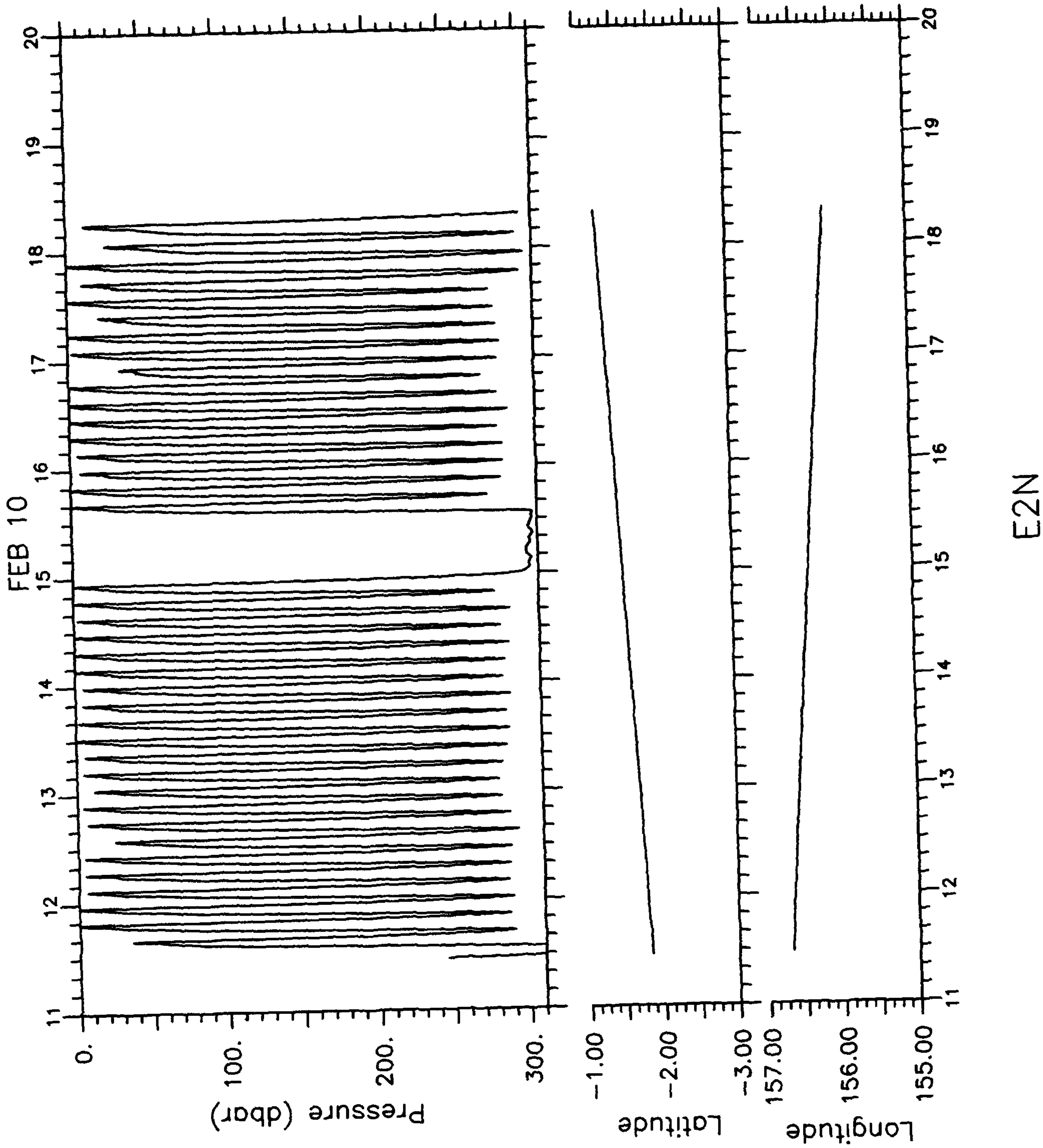

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−3.00
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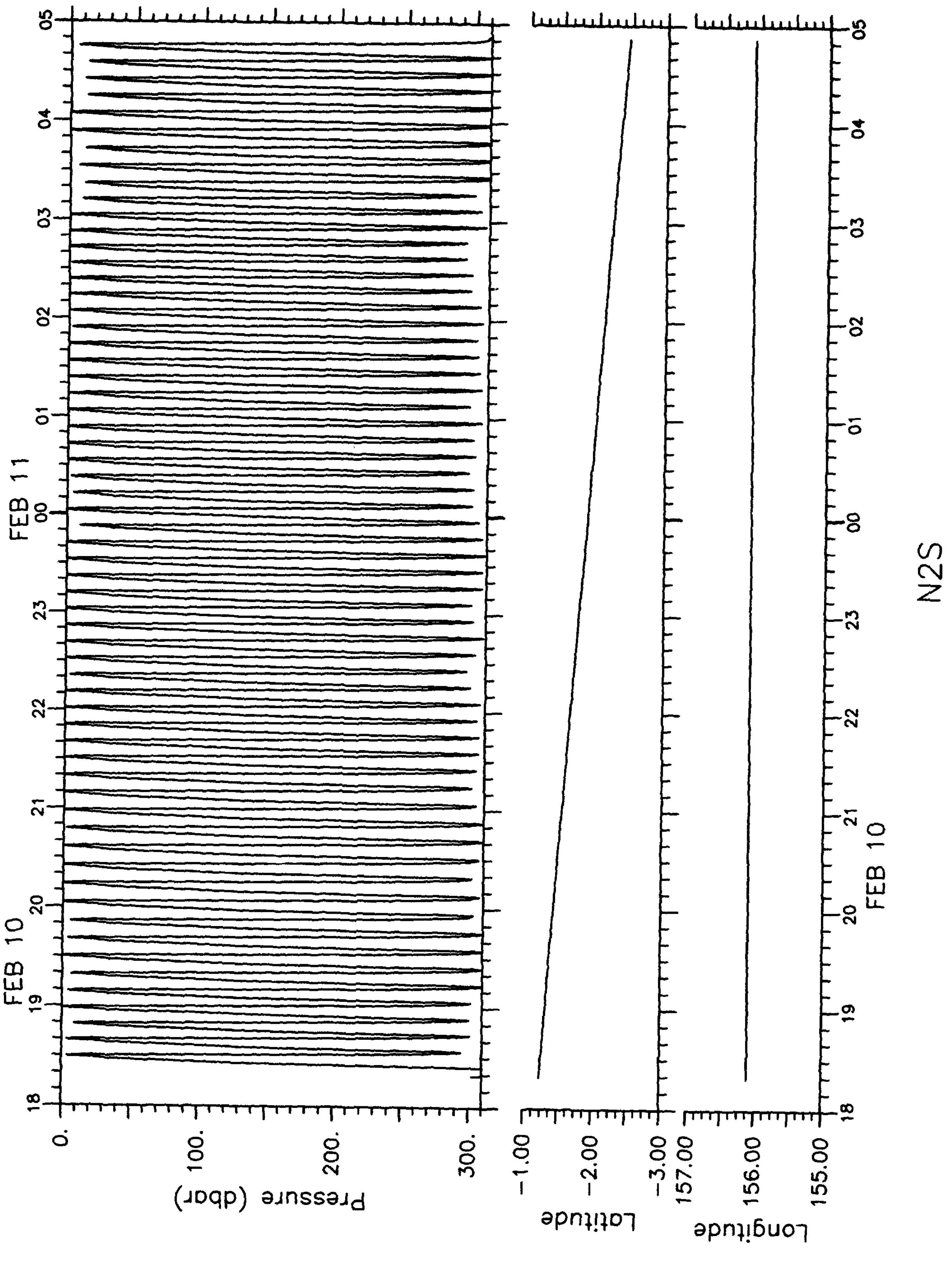

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FEB 11
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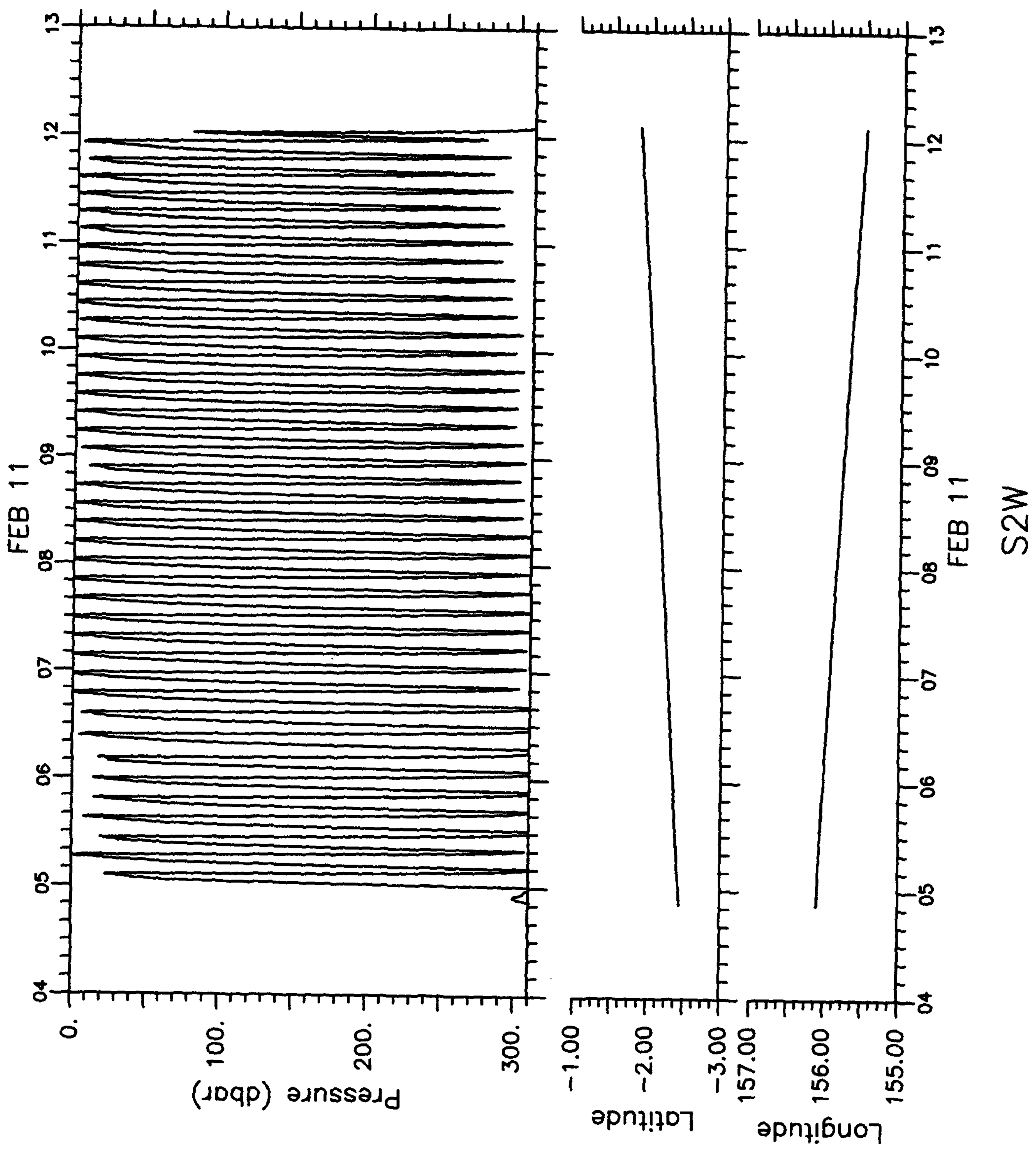
N2S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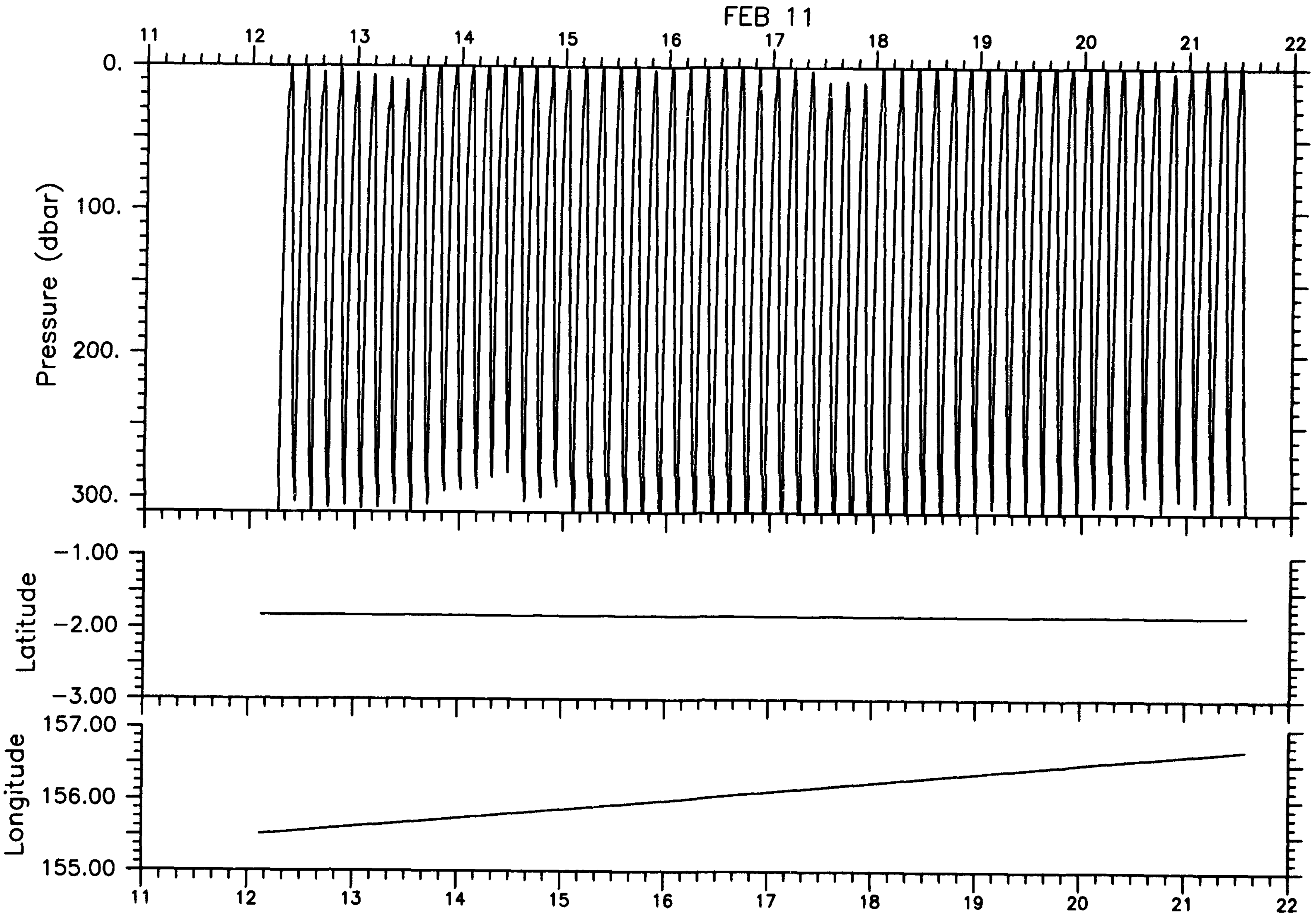
FEB 11
S2W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-3.00
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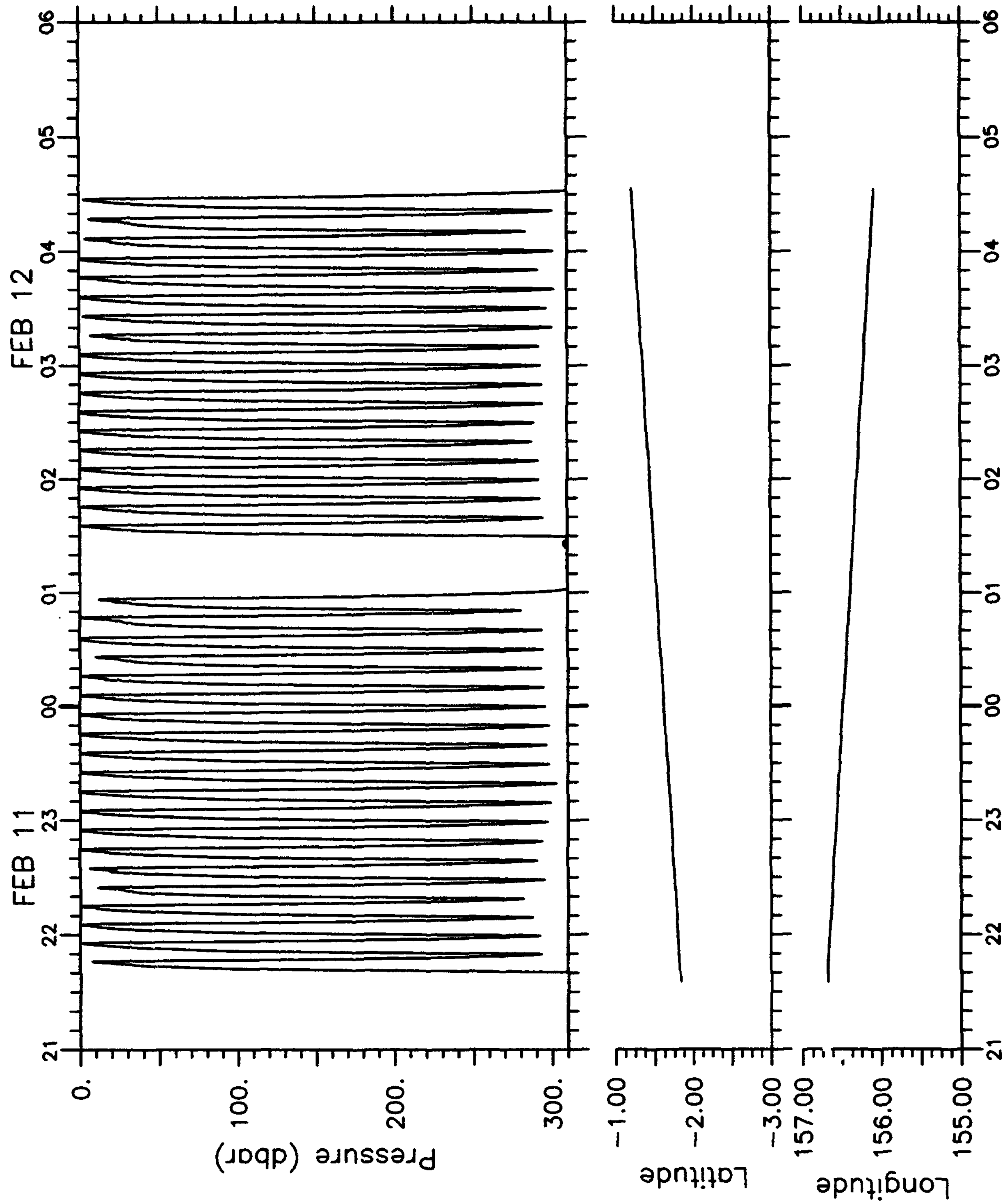
Longitude

W2E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Longitude
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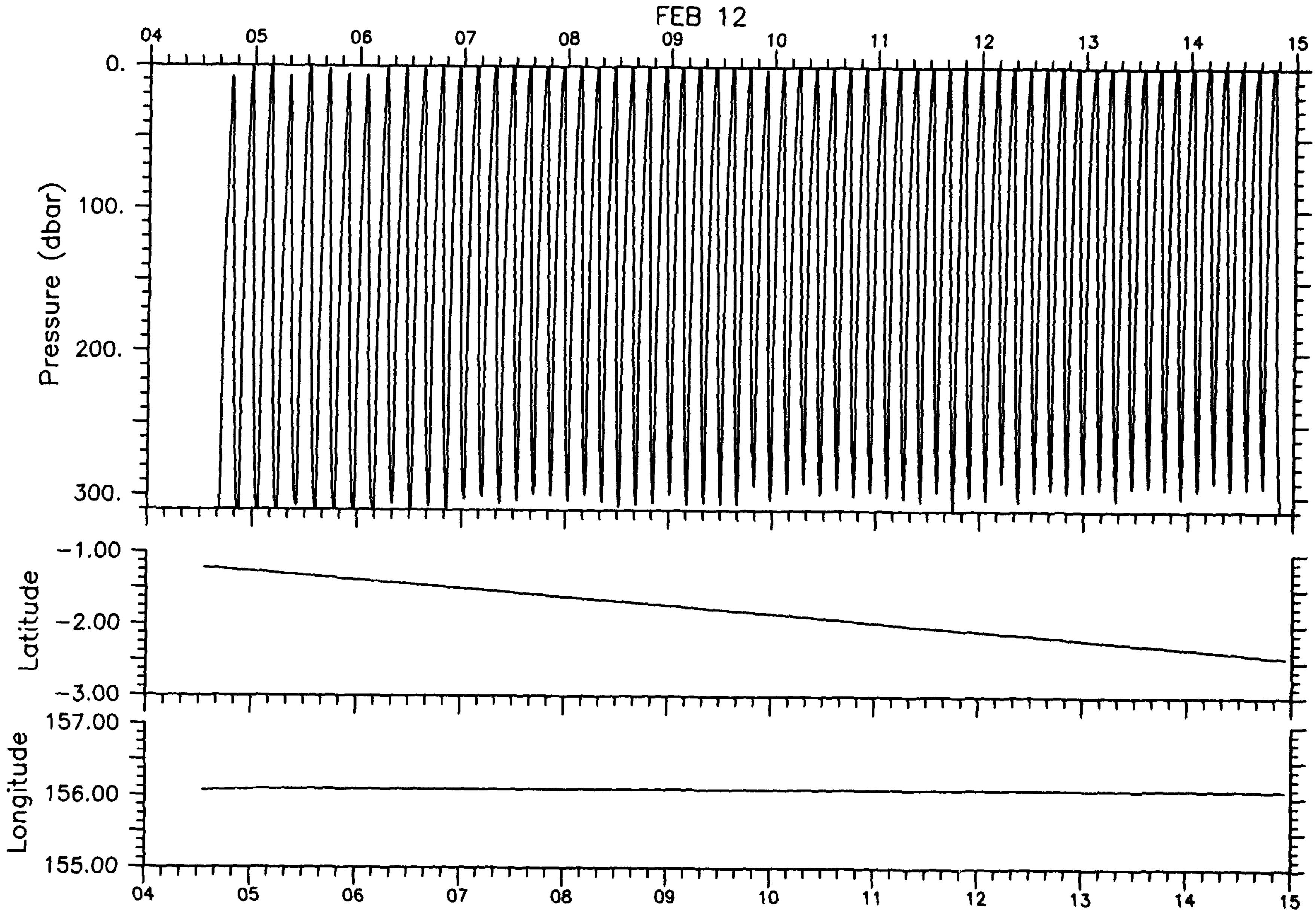
E2N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Longitude
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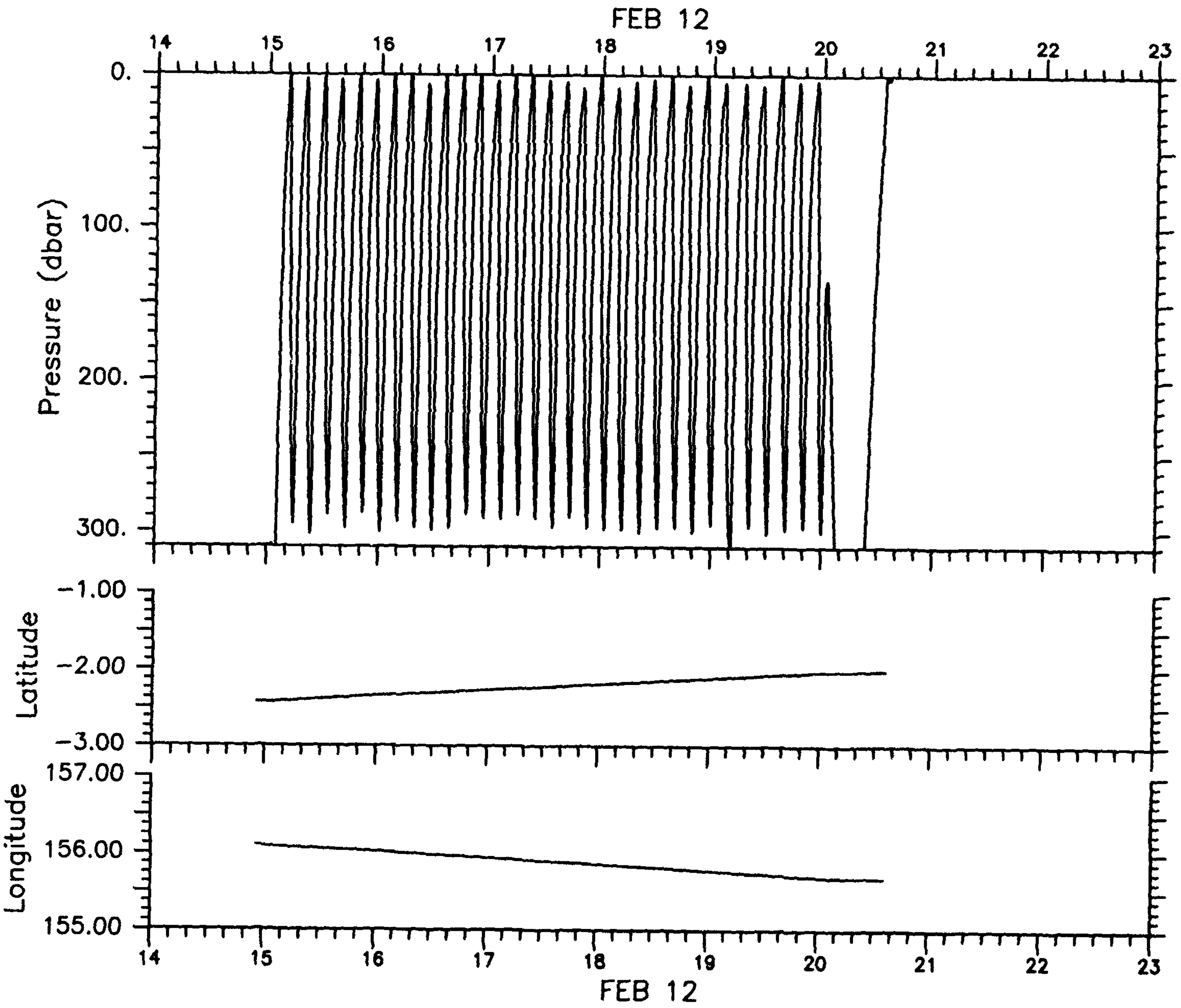
N2S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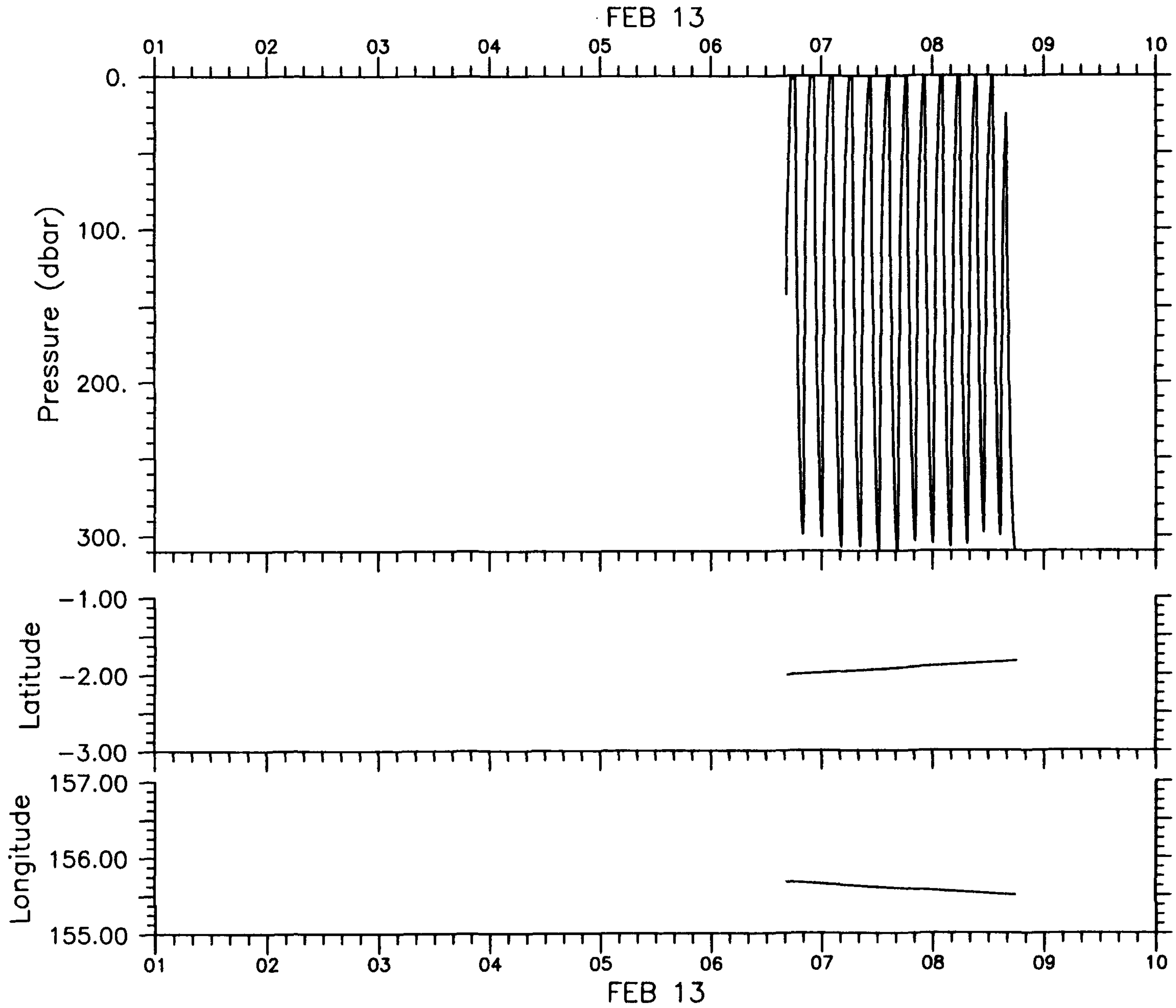
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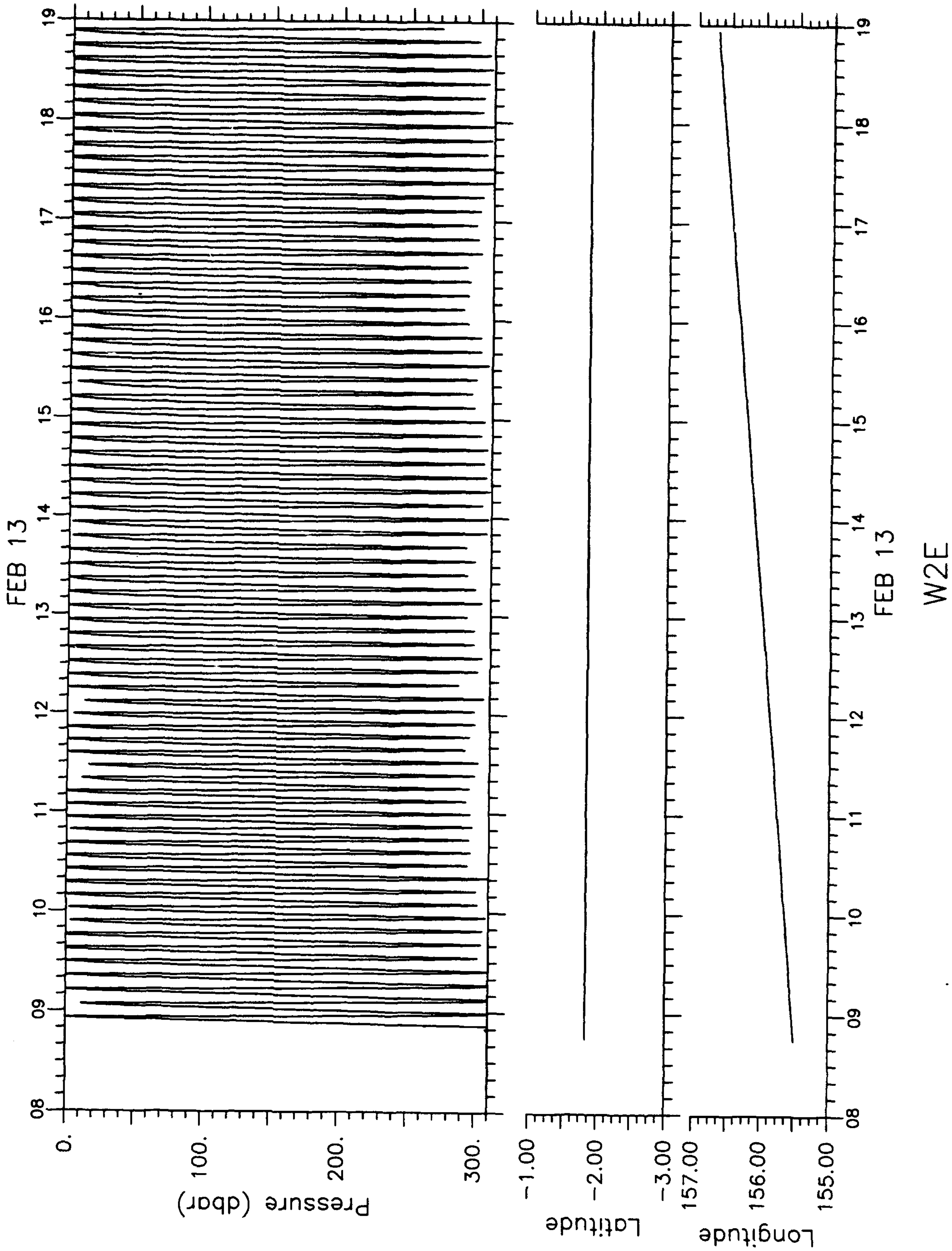
FEB 13

S2W



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-3.00
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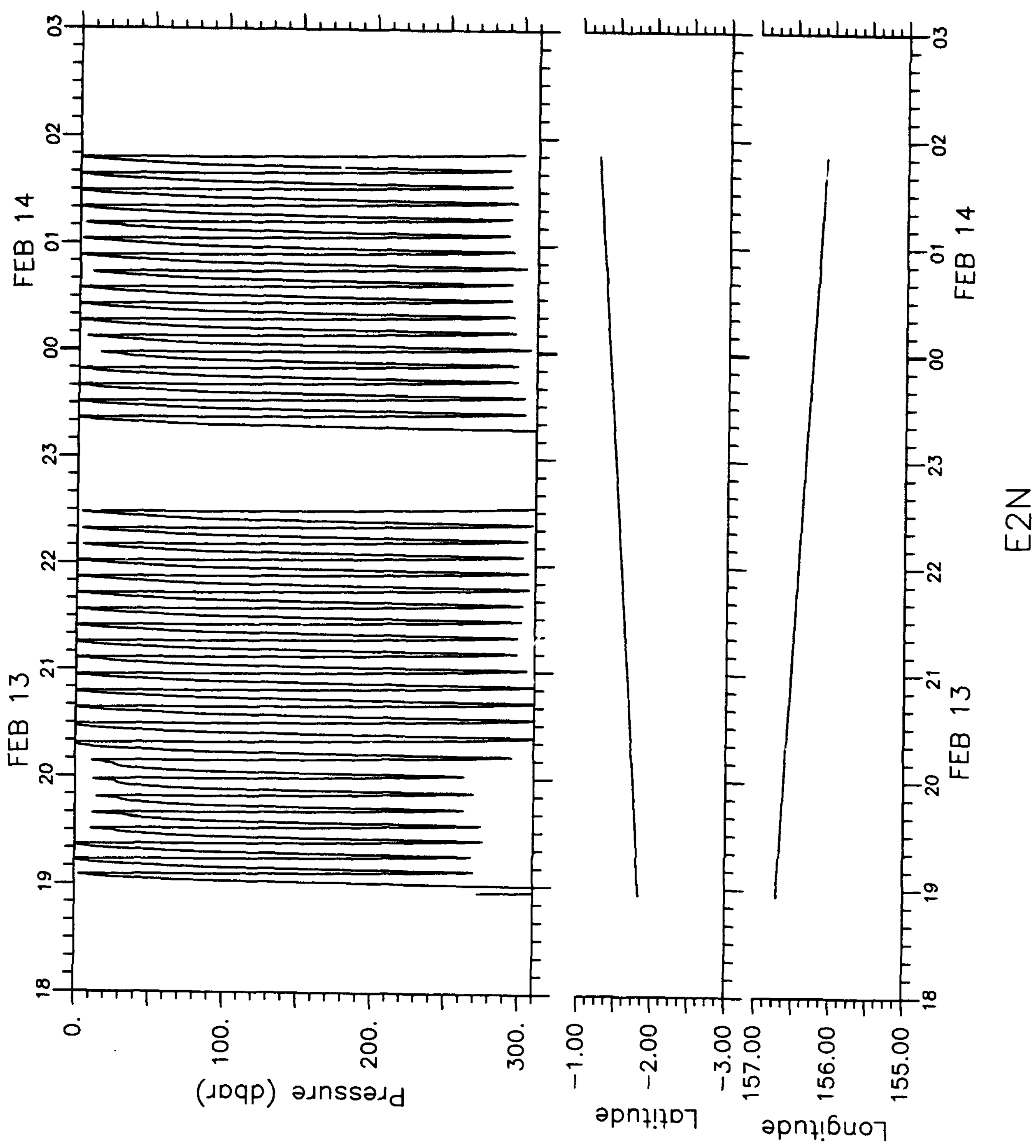
W2E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FEB 14
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Latitude
157.00
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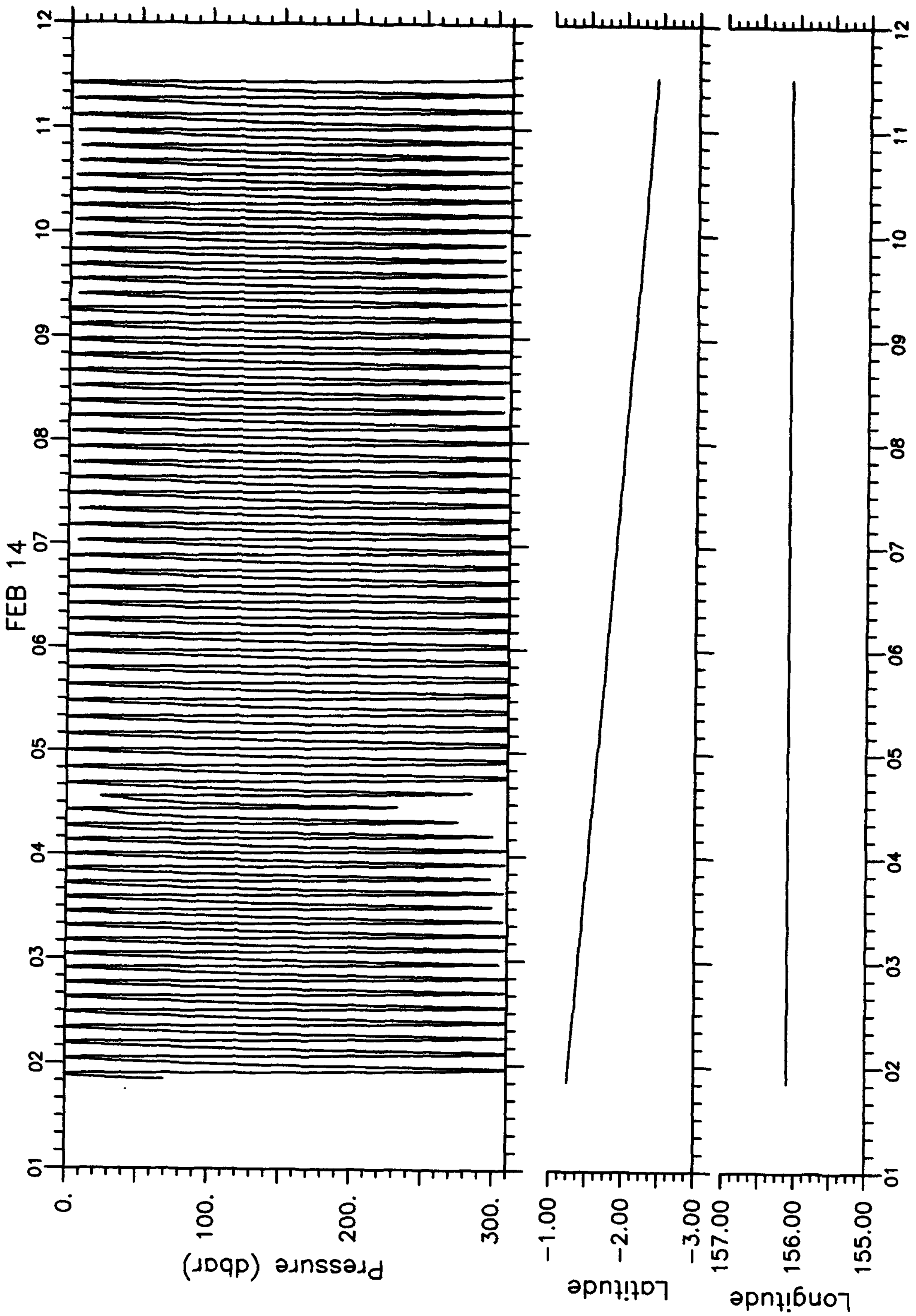
Longitude
E2N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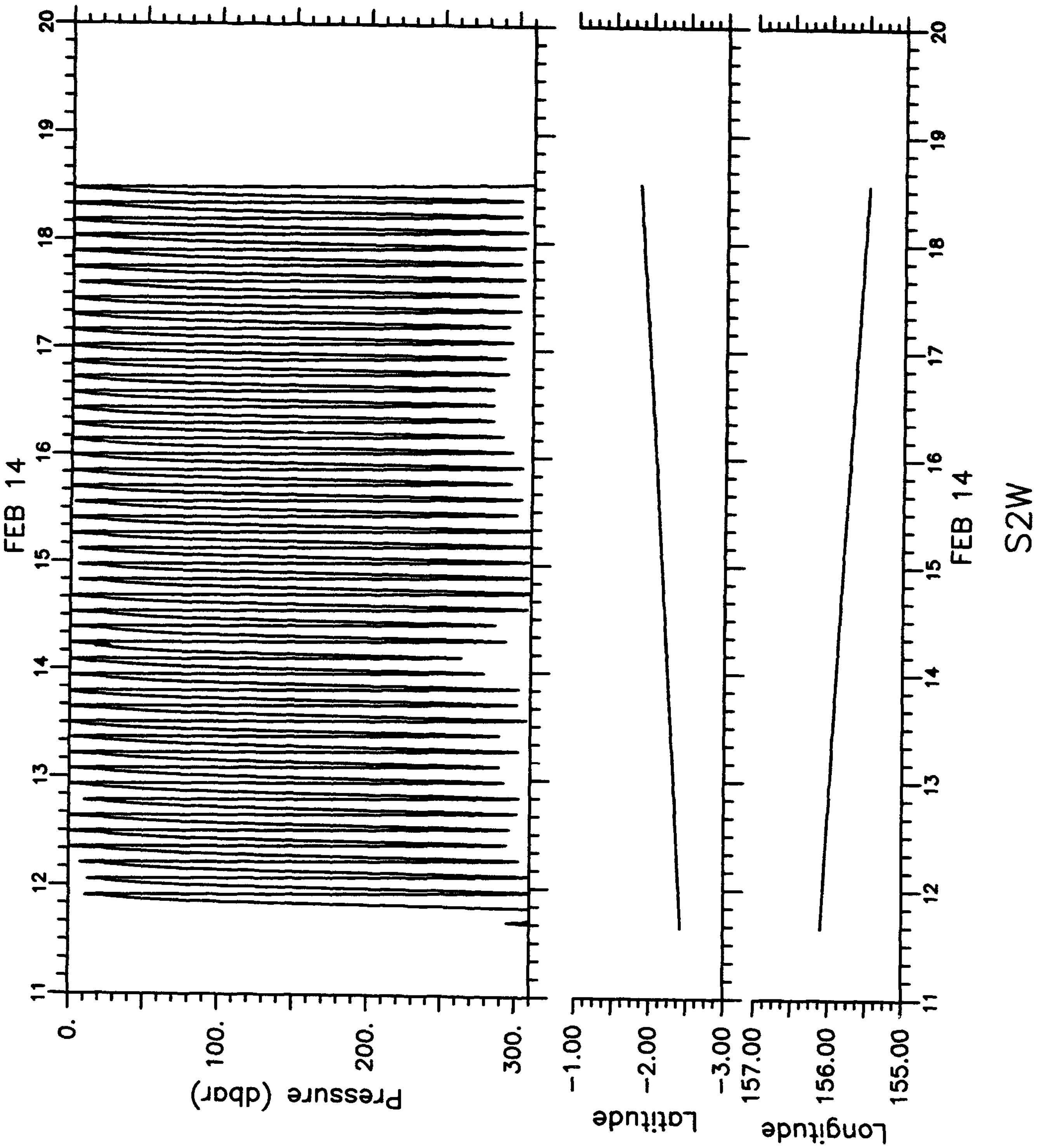
N2S



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200.
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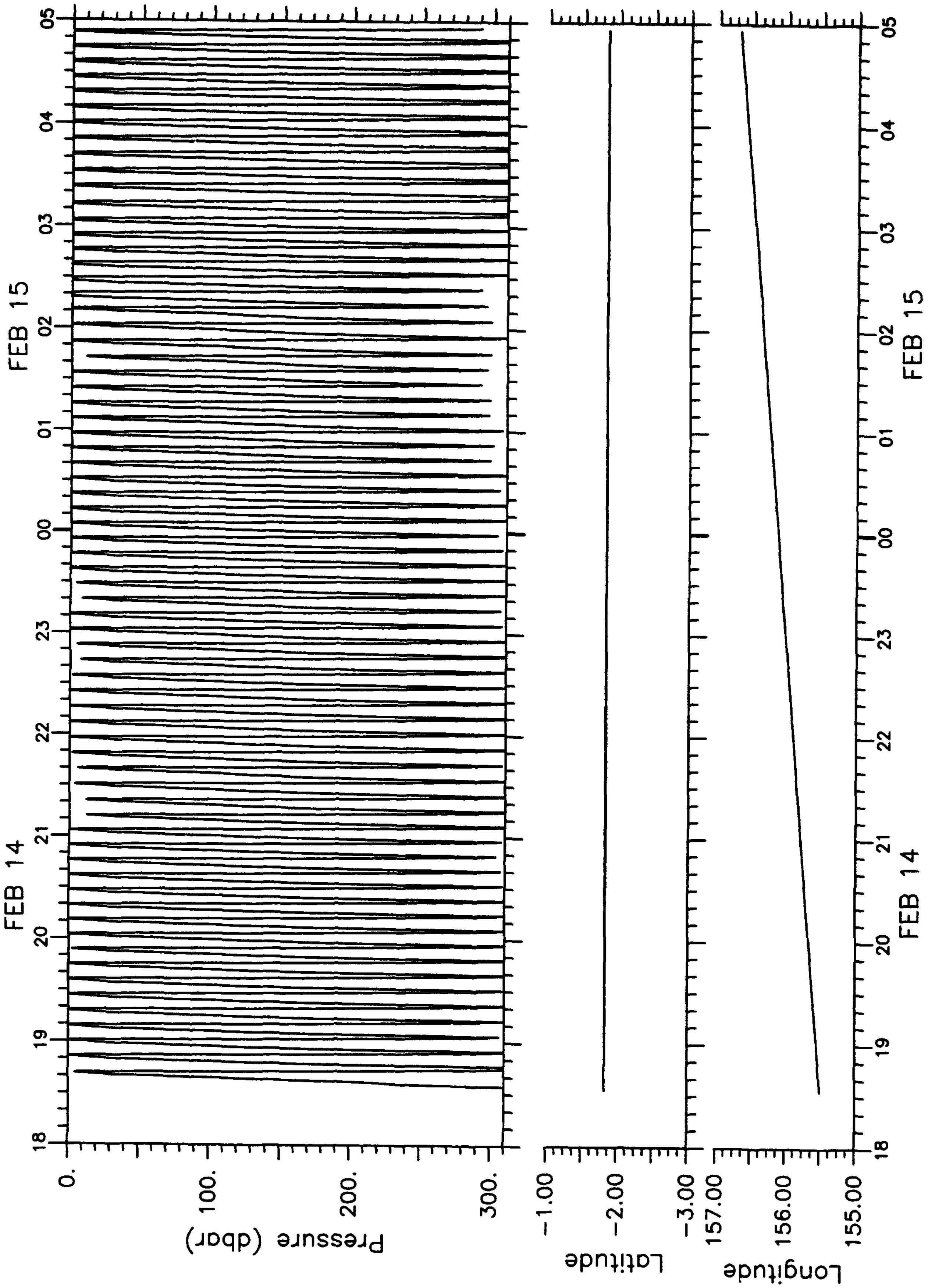
S2W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FEB 15
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01
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04
05
Pressure (dbar)
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Latitude
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-3.00
Longitude
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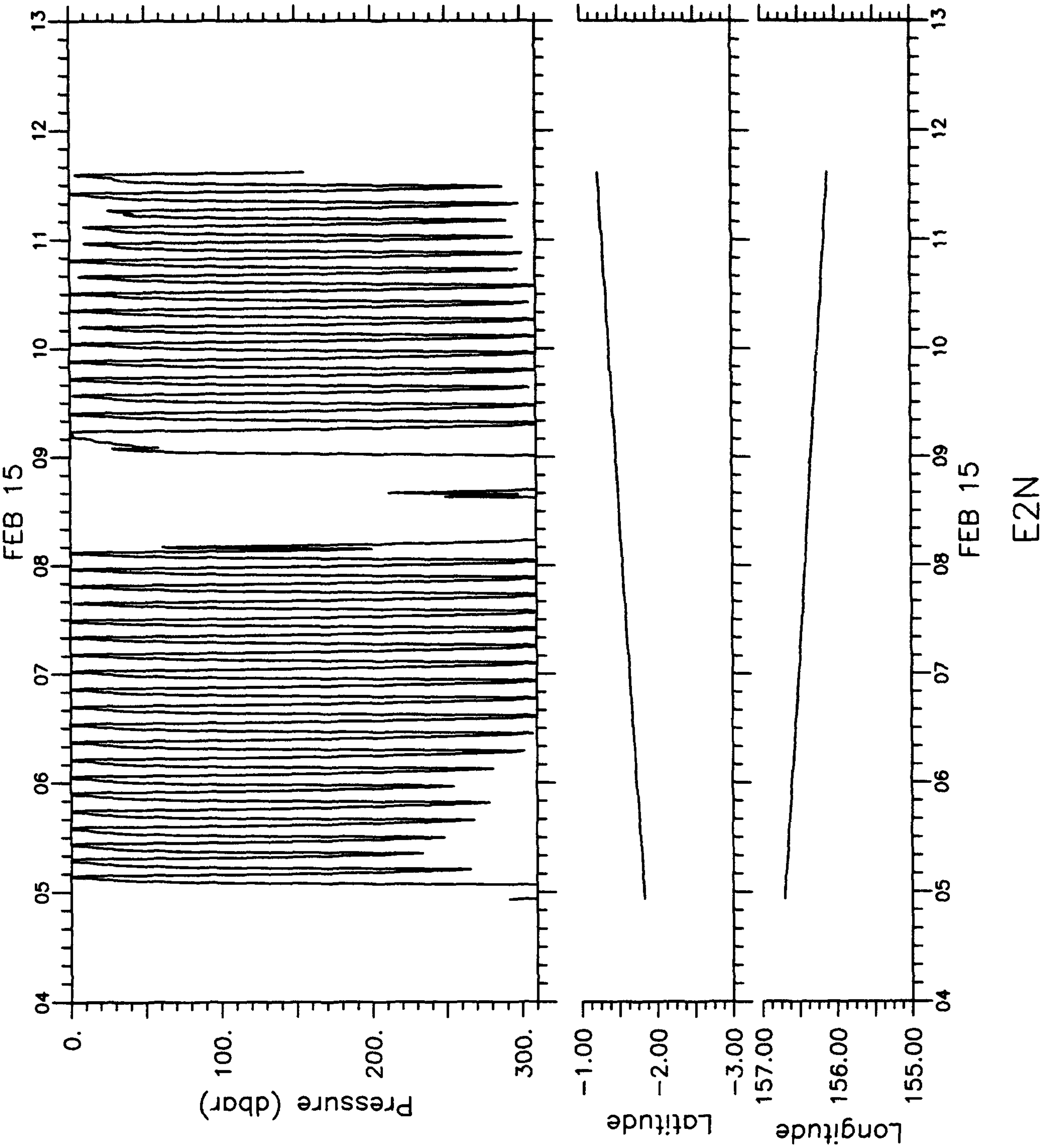
156.00
155.00

W2E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-3.00
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155.00
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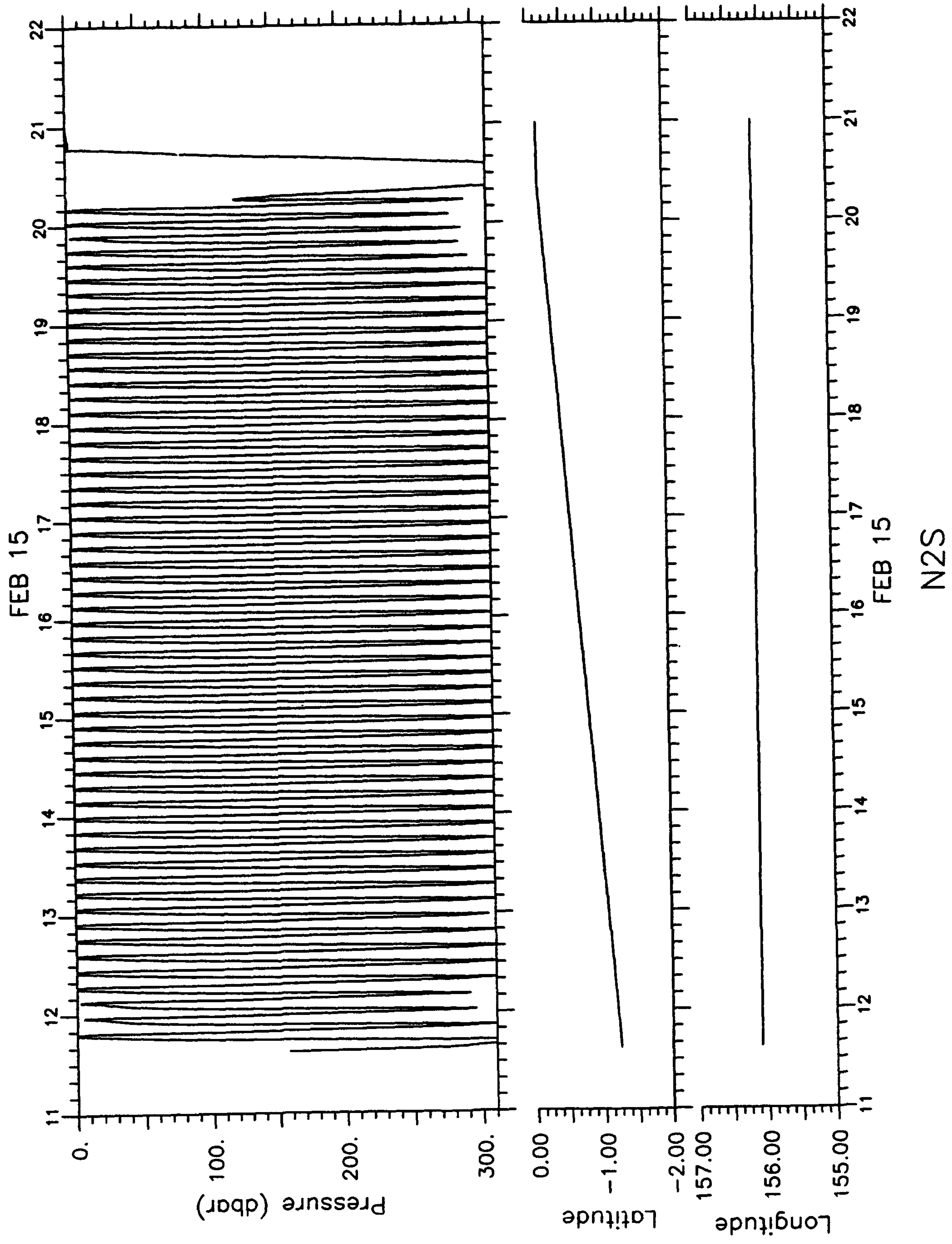
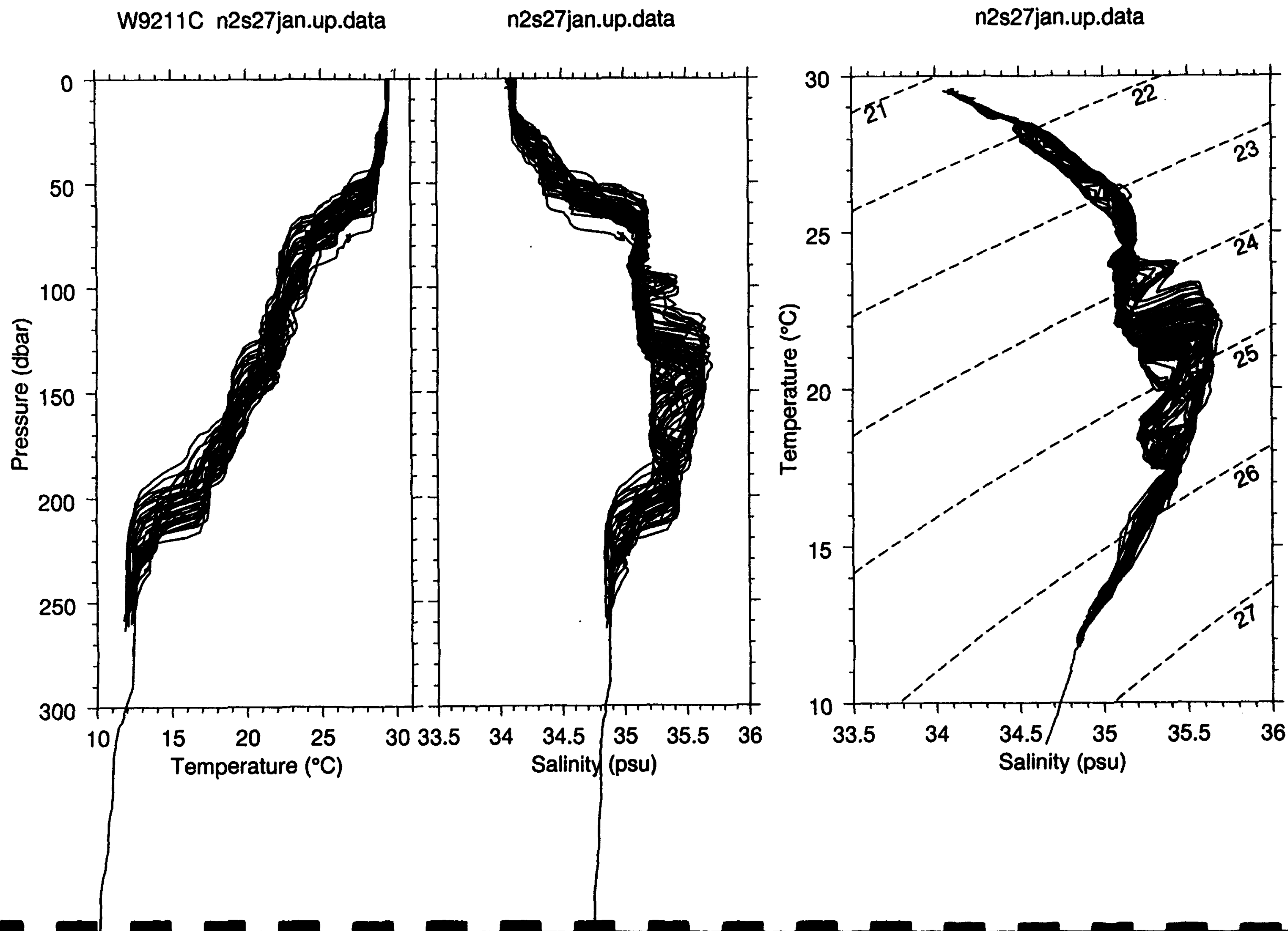
FEB 15
E2N


FEB 15
N2S
Pressure (dbar)
Latitude
Longitude

ENSEMBLE PROFILES

OF

SEASOAR TEMPERATURE AND SALINITY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Pressure (dbar)
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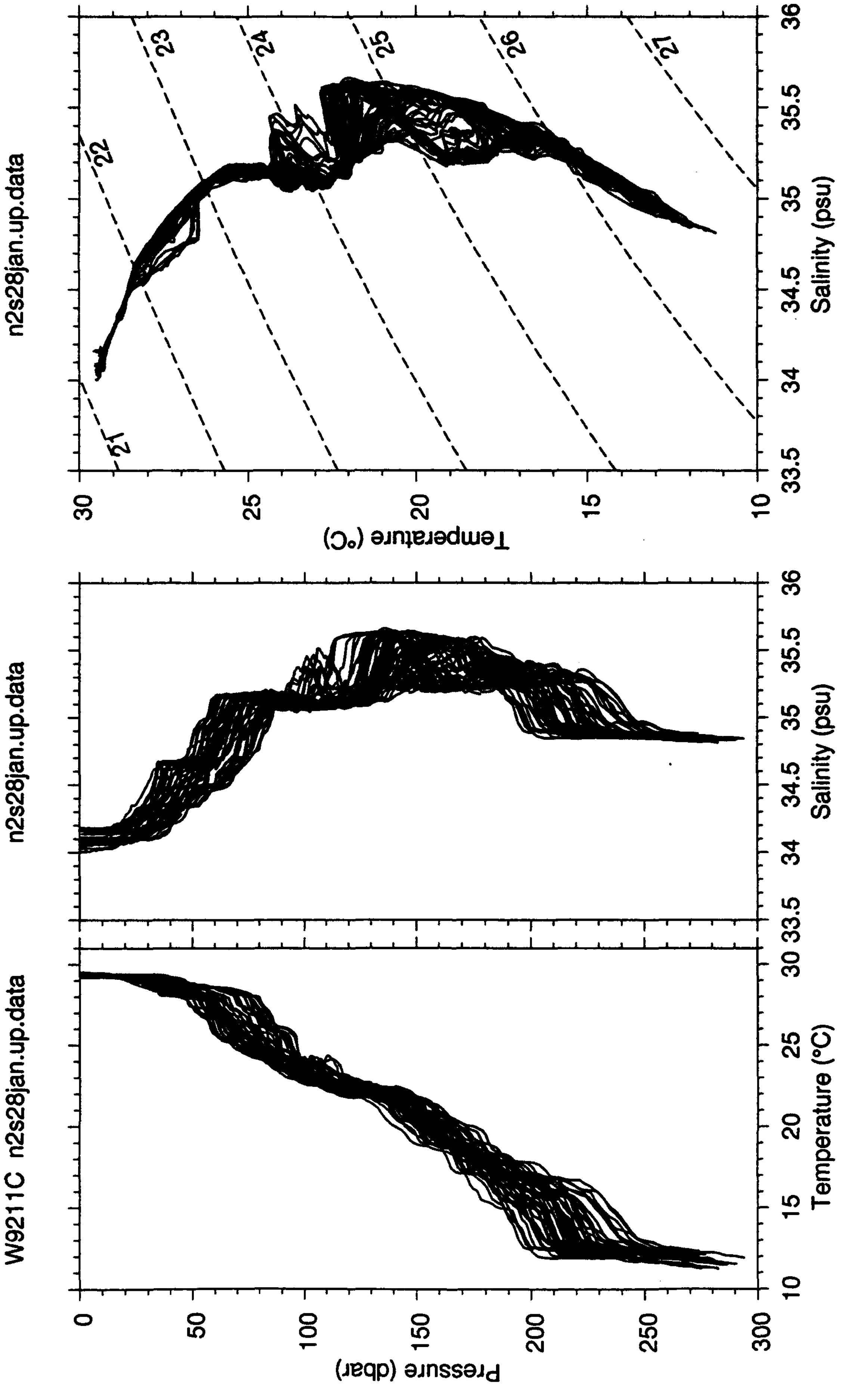
50
100
150
200
250
300
10
15
20
25
30
Temperature (°C)
33.5
34
34.5
35
35.5
36
Salinity (psu)
Temperature (°C)
21
22
23
24
25
26
27
Salinity (psu)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100
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200
250
300
10
15
20
25
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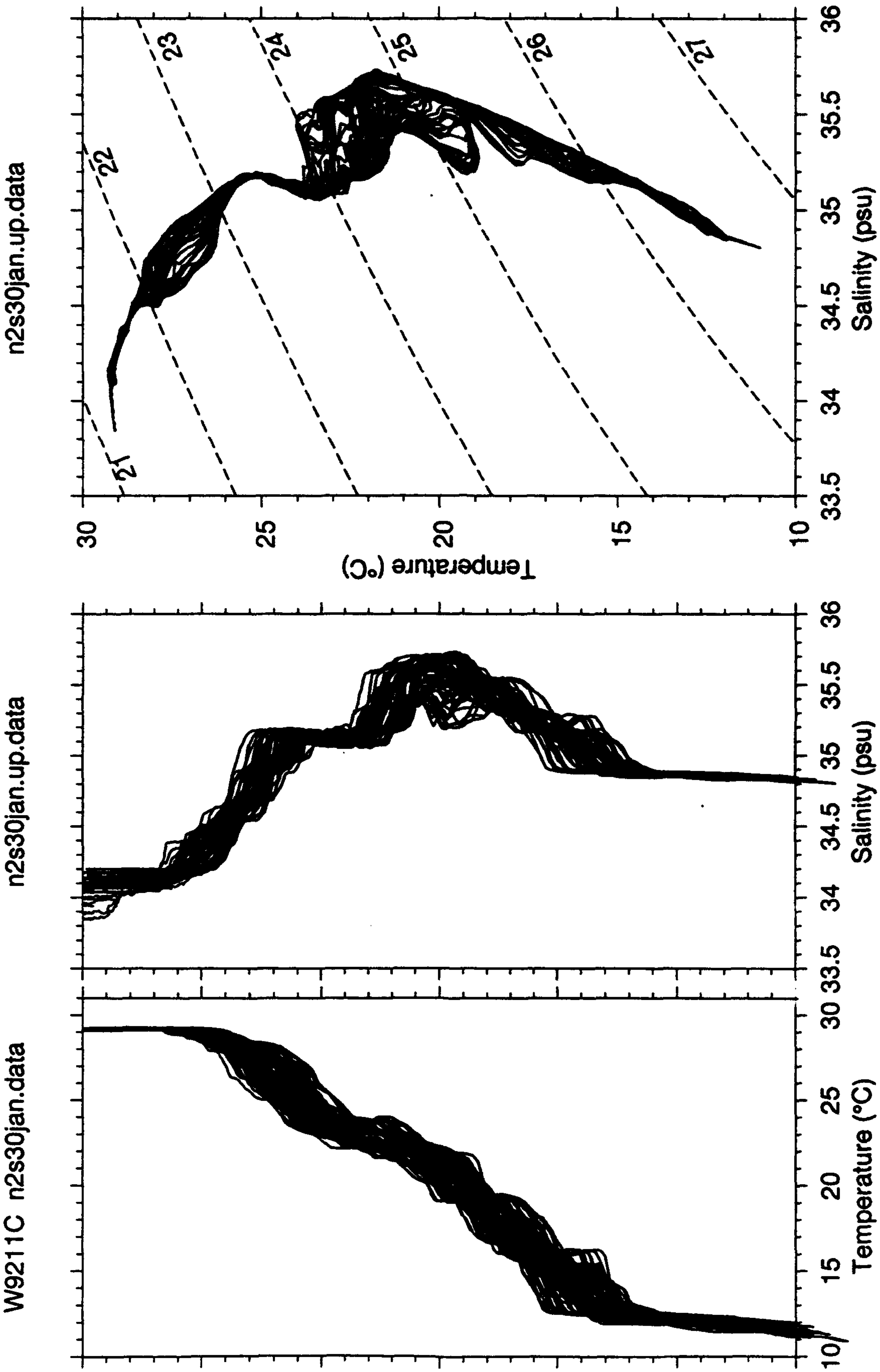
Temperature (°C)
n2s28jan.up.data
33.5
34
34.5
35
35.5
36
Salinity (psu)
n2s28jan.up.data
Temperature (°C)
30
25
20
15
10
33.5
34
34.5
35
35.5
36
Salinity (psu)
21
22
23
24
25
26
27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n2s30jan.up.data
Pressure (dbar)
Temperature (°C)
Salinity (psu)
Temperature (°C)
Salinity (psu)
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23
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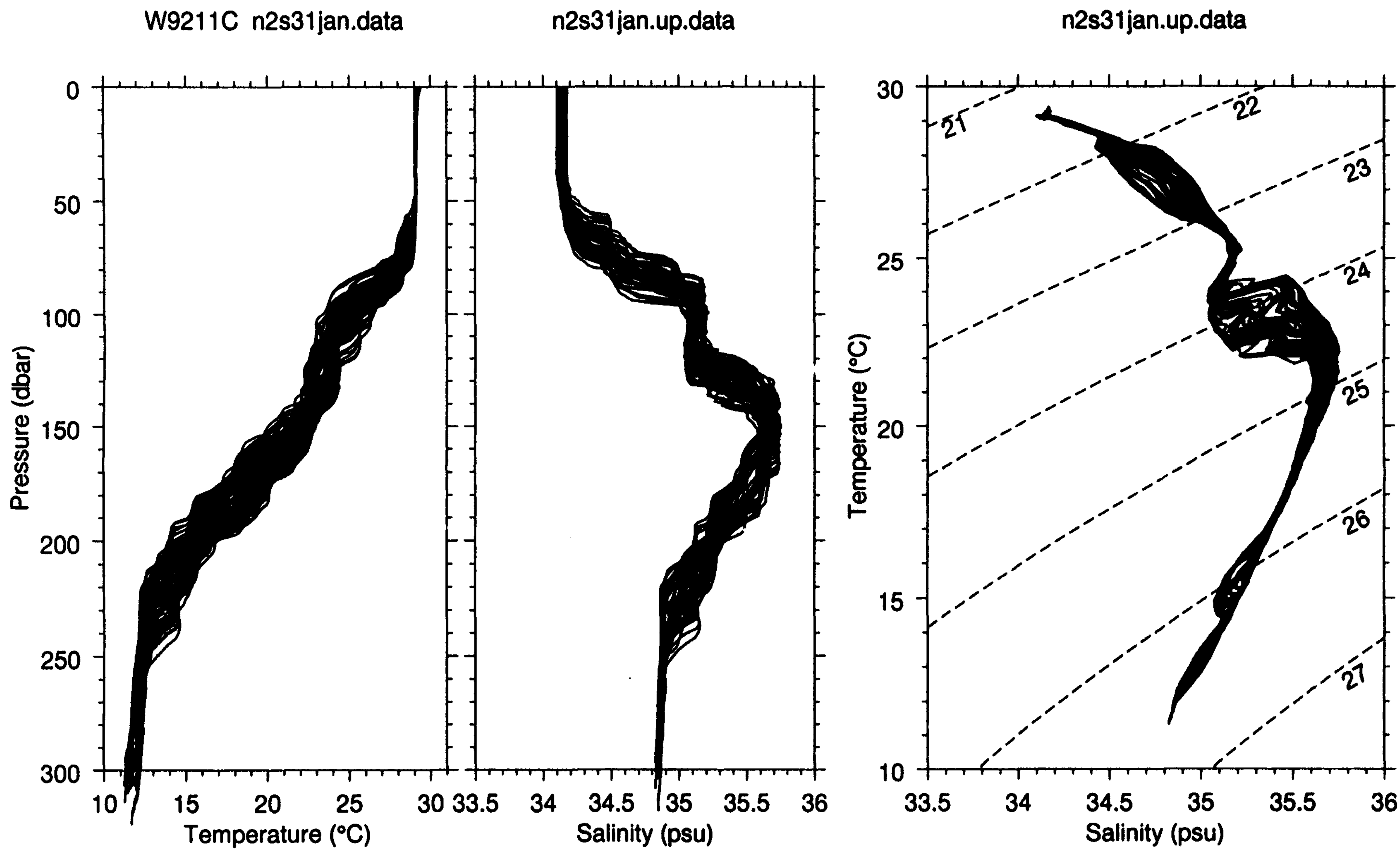
27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200
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Temperature (°C)
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Salinity (psu)
Temperature (°C)
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Salinity (psu)
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23
24
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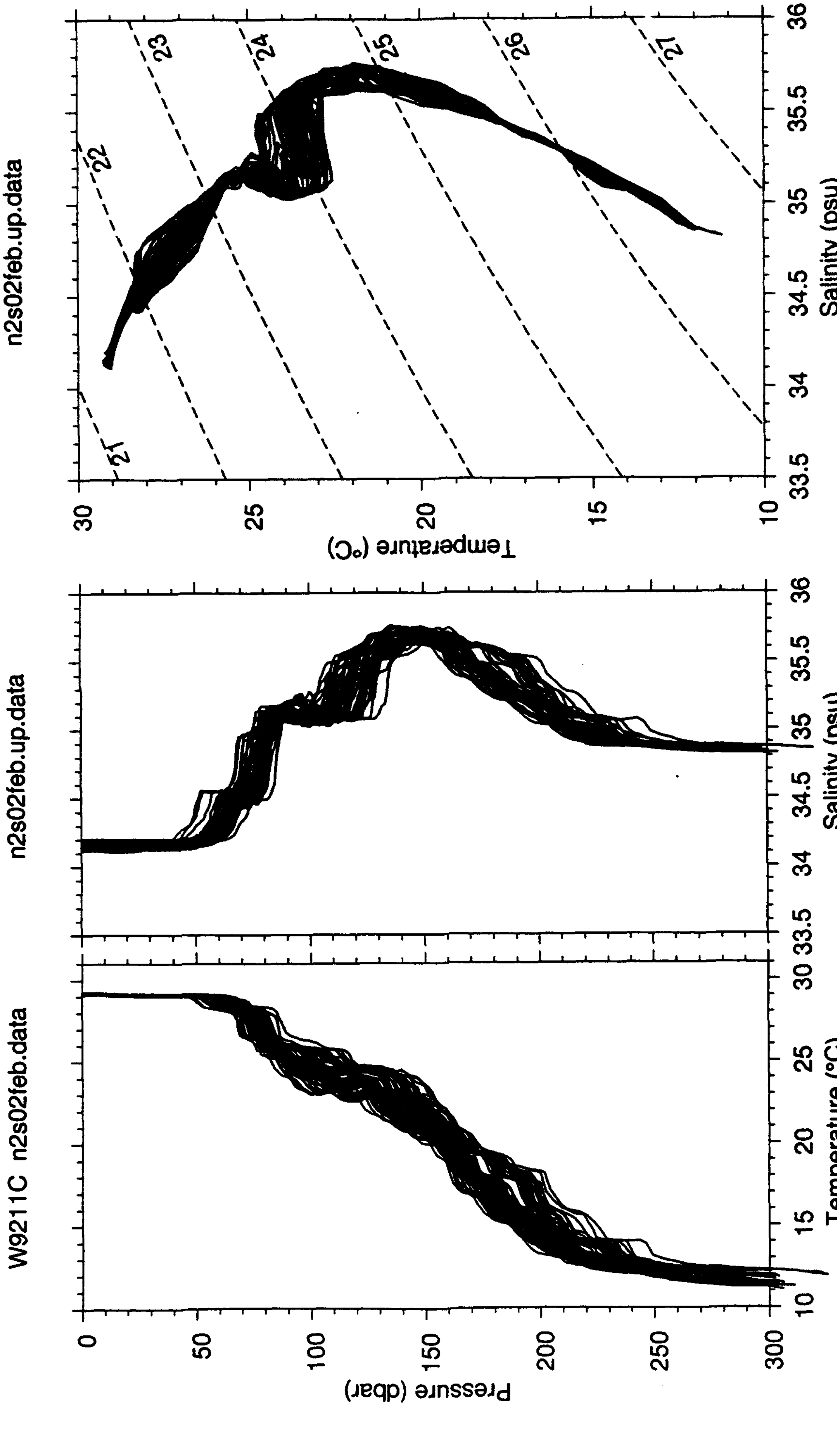
27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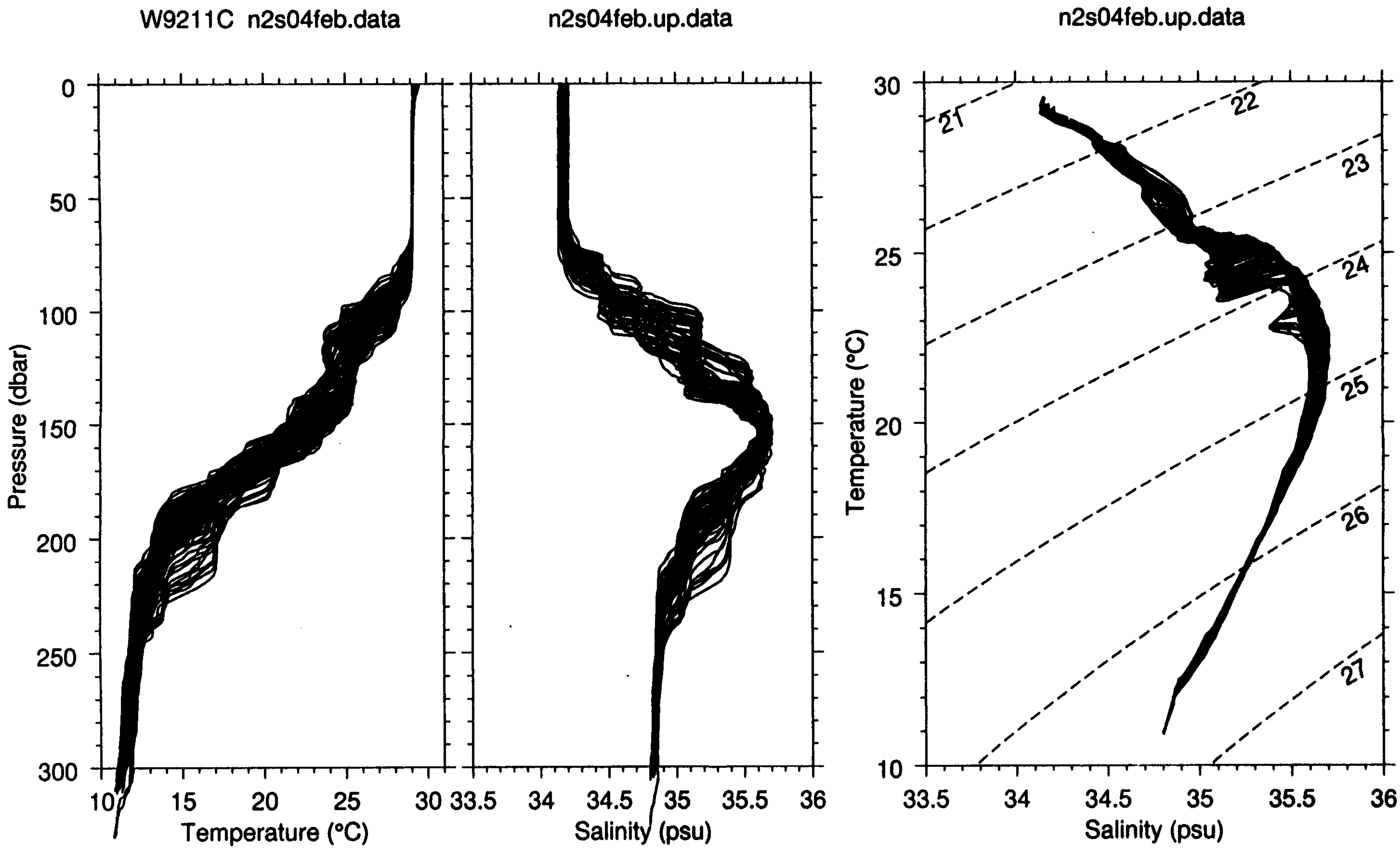
Temperature (°C)
Salinity (psu)
Salinity (psu)
Temperature (°C)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Pressure (dbar)
Temperature (°C)
Salinity (psu)
Temperature (°C)
Salinity (psu)
0
50
100
150
200
250
300
10
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30
33.5
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34.5
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35.5
36
21
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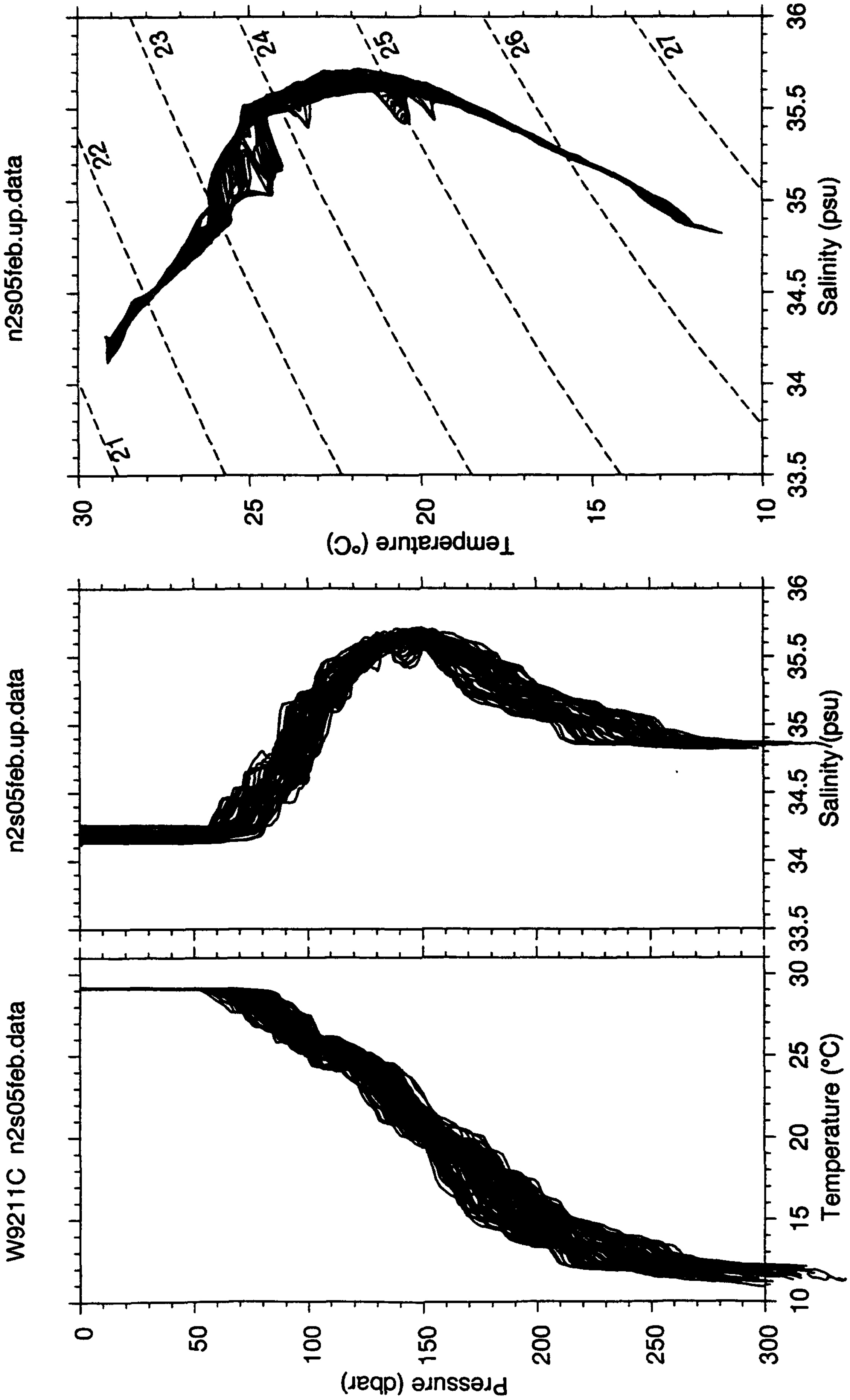
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Salinity (psu)
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Salinity (psu)
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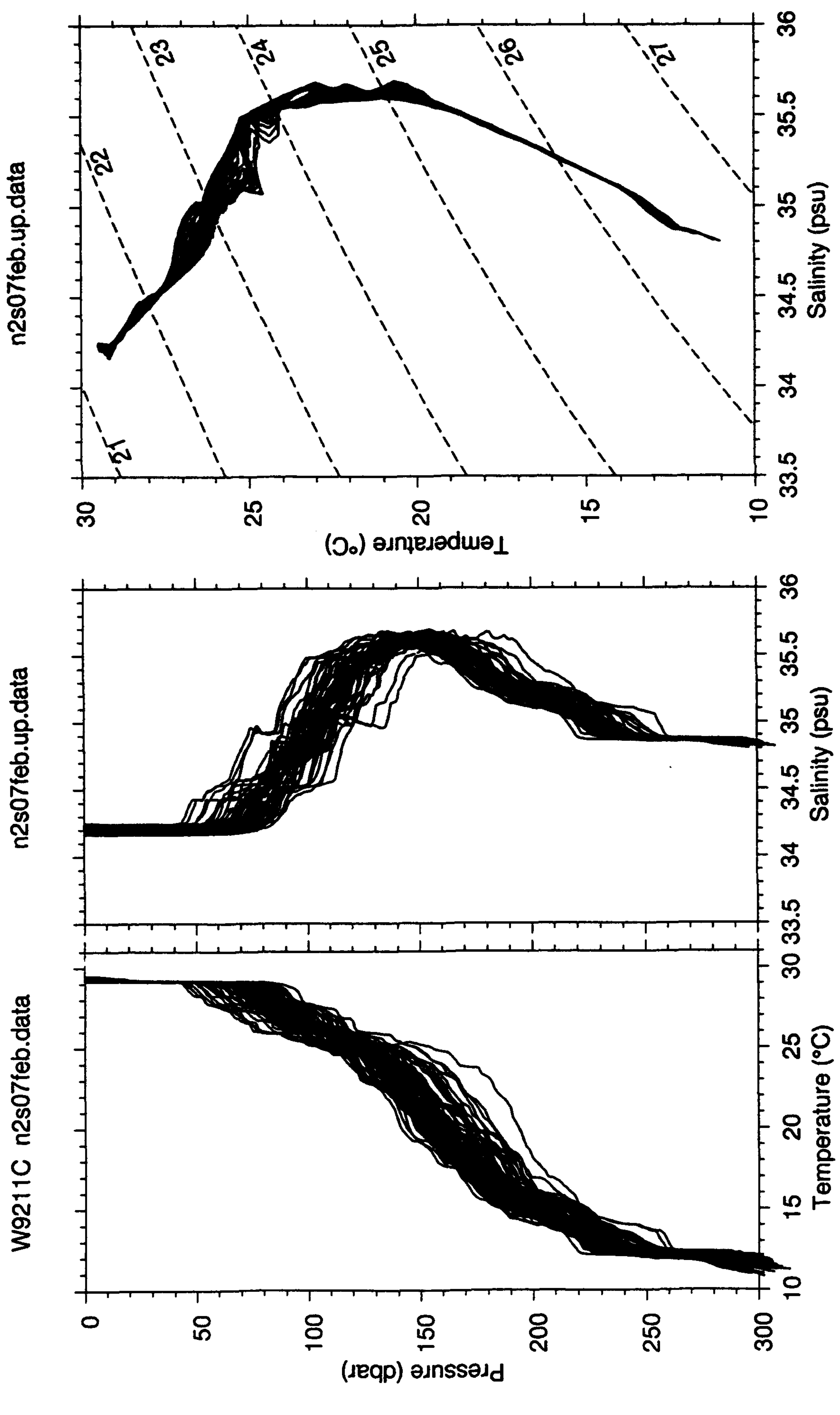
27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Salinity (psu)
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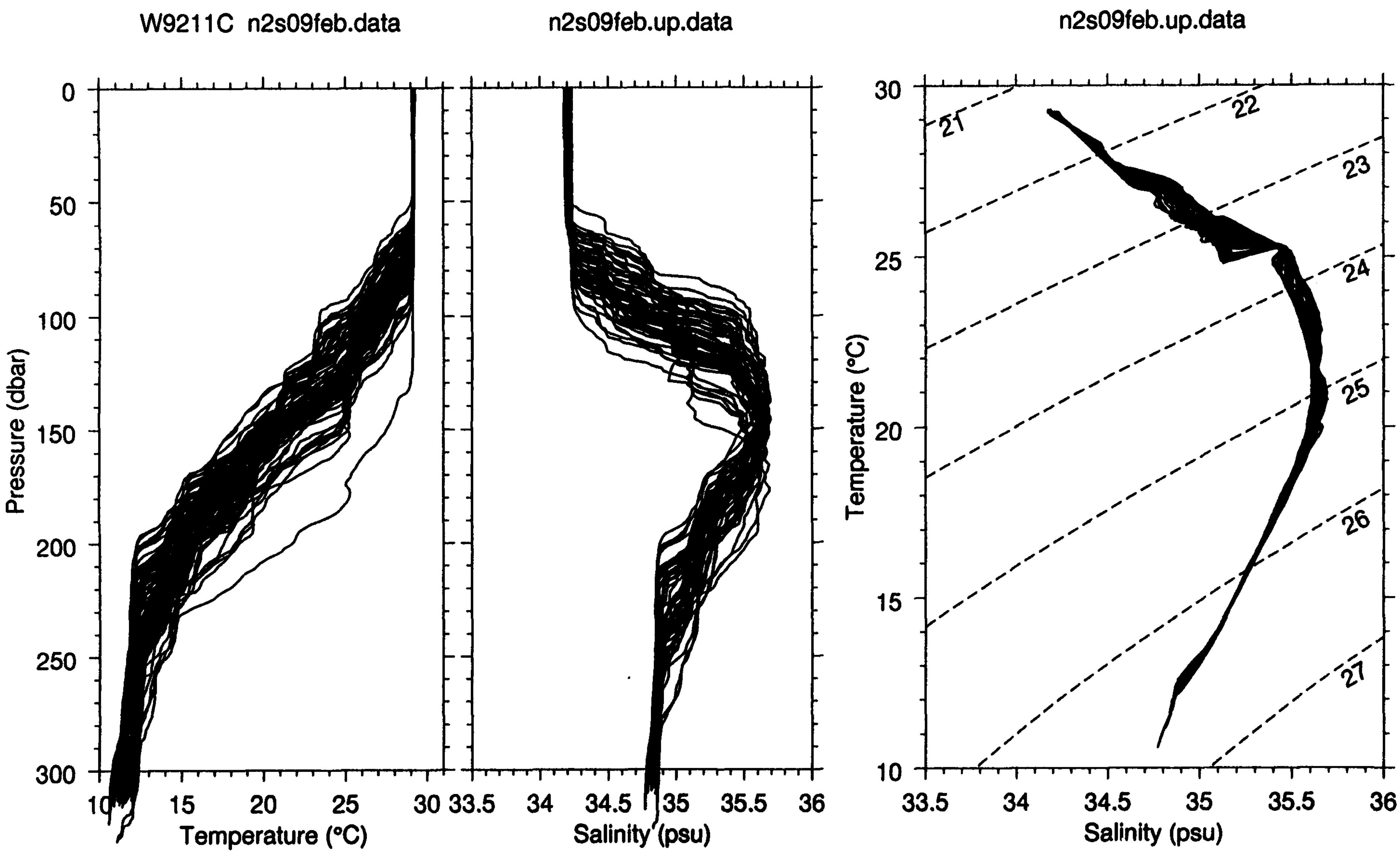

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Temperature (°C)
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Temperature (°C)
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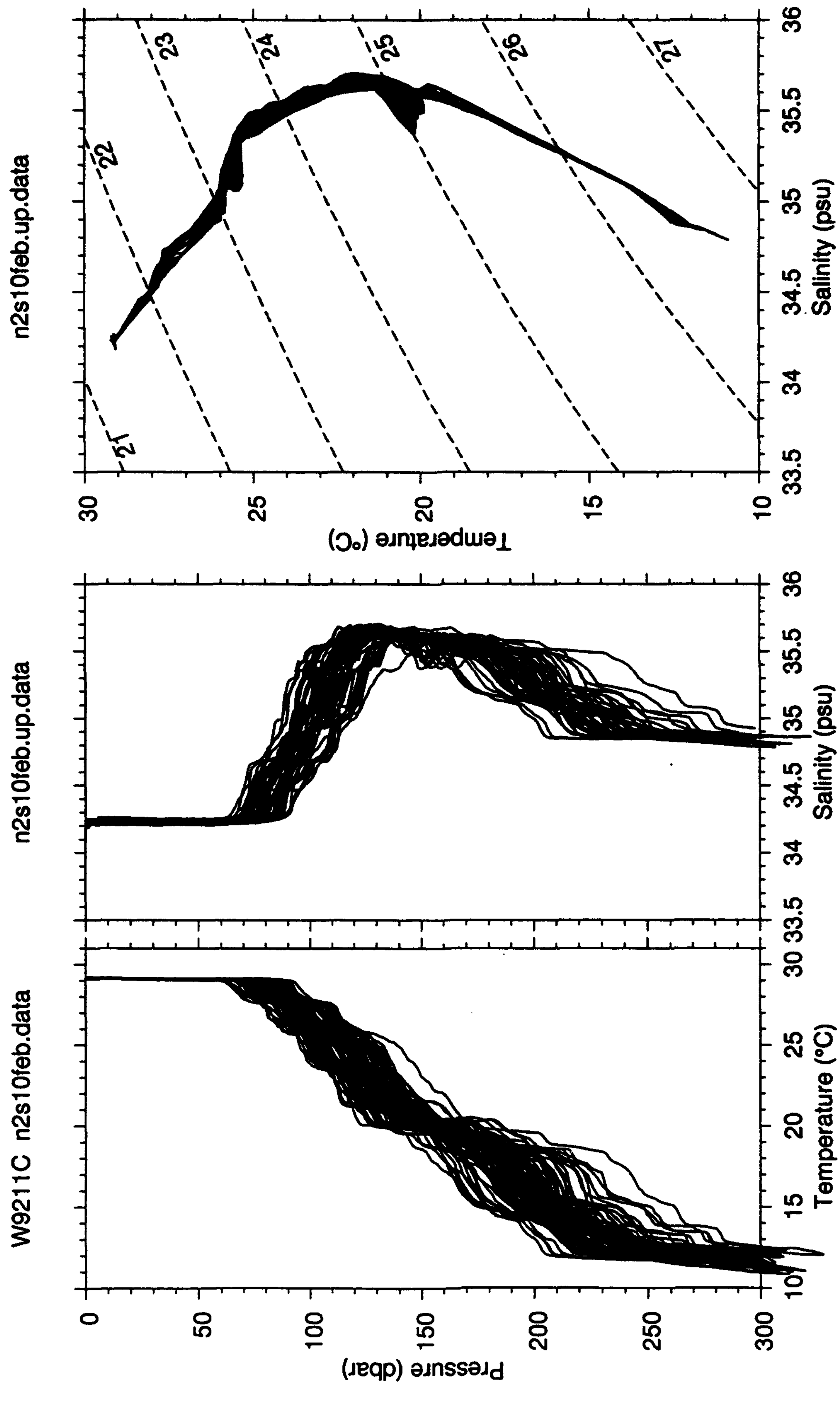
23
24
25
26
27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250
300
Temperature (°C)
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15
20
25
30
Salinity (psu)
33.5
34
34.5
35
35.5
36
Temperature (°C)
10
15
20
25
30
Salinity (psu)
33.5
34
34.5
35
35.5
36
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24
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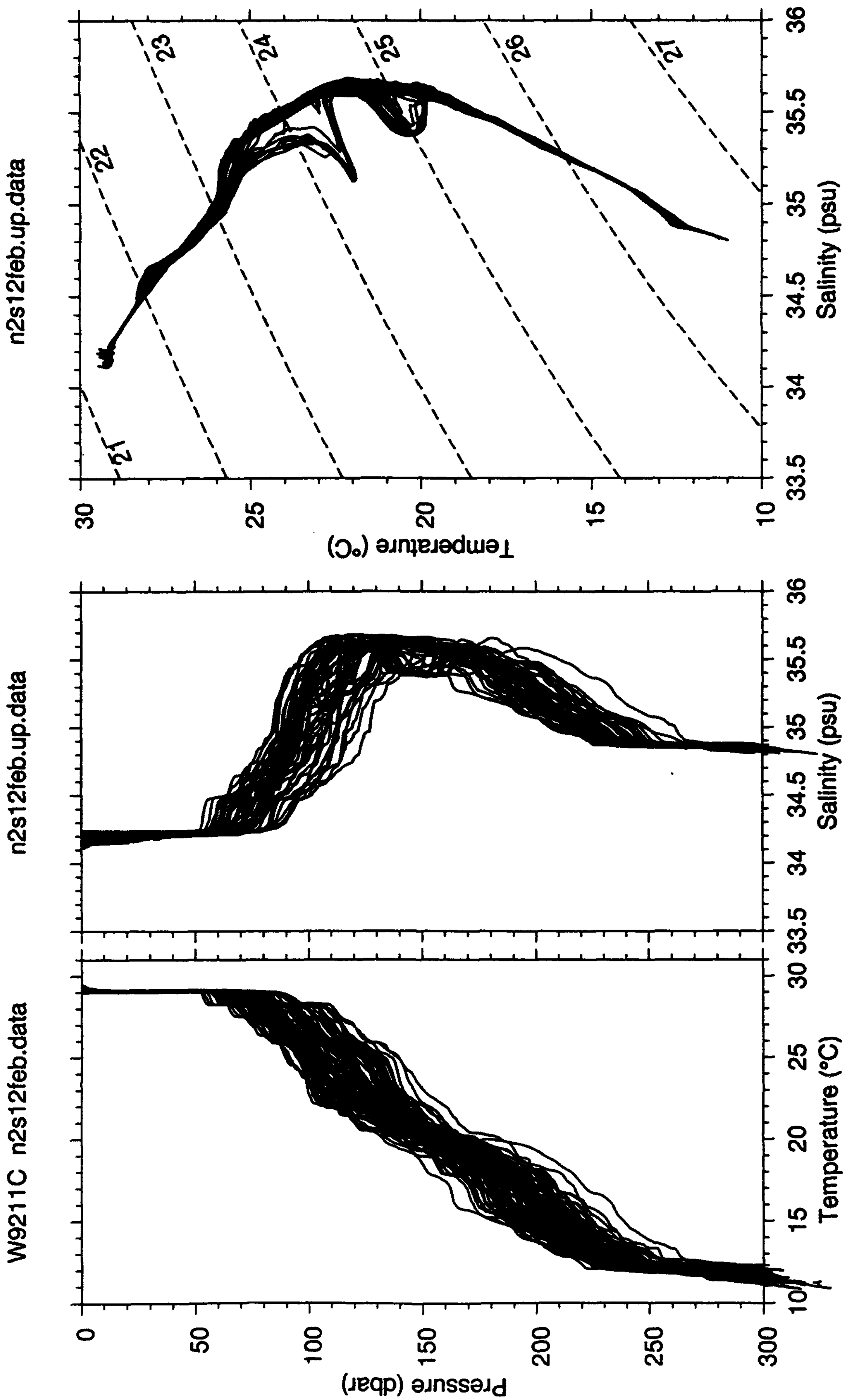
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Salinity (psu)
Temperature (°C)
Salinity (psu)
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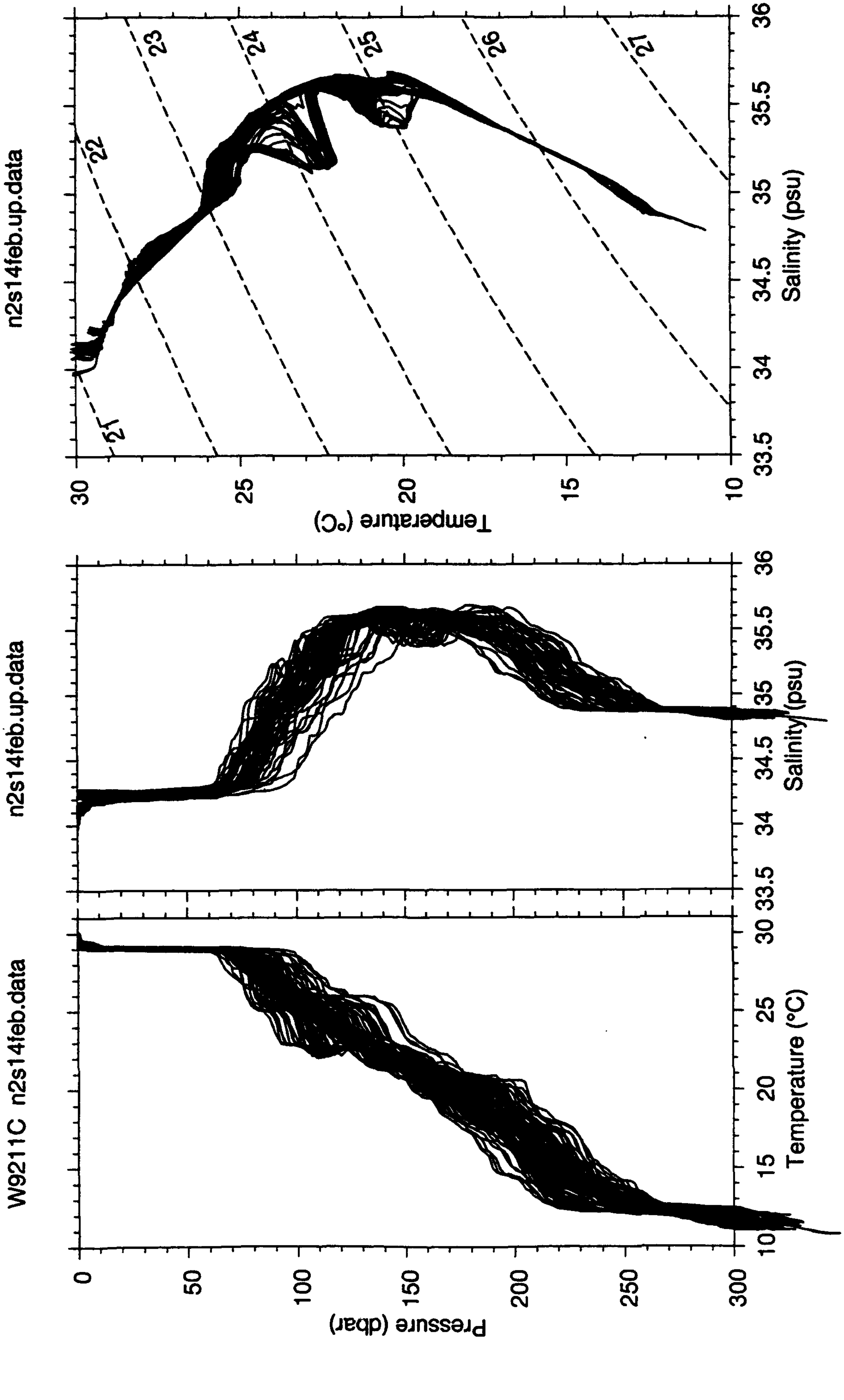
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Salinity (psu)
Salinity (psu)
Temperature (°C)
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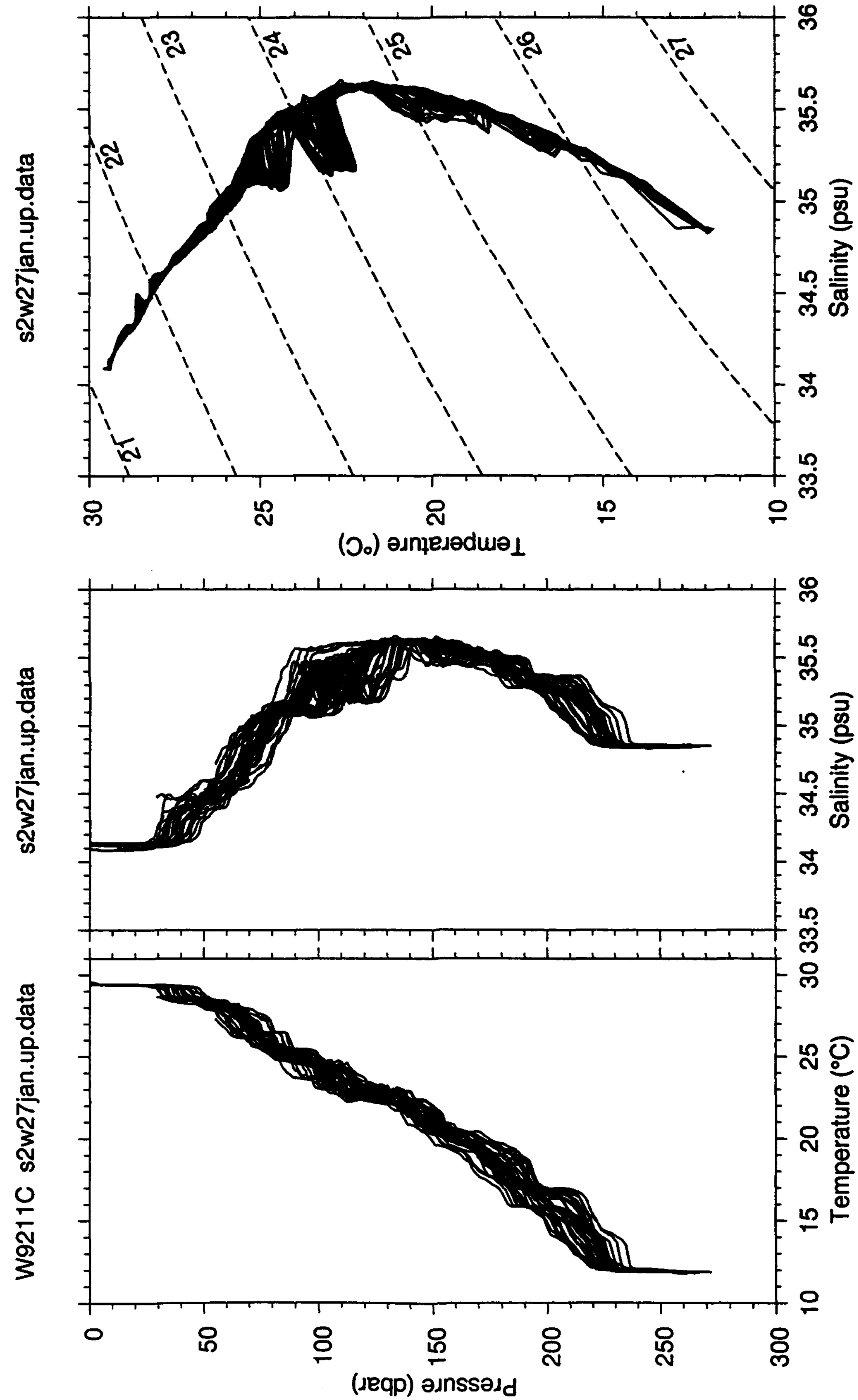
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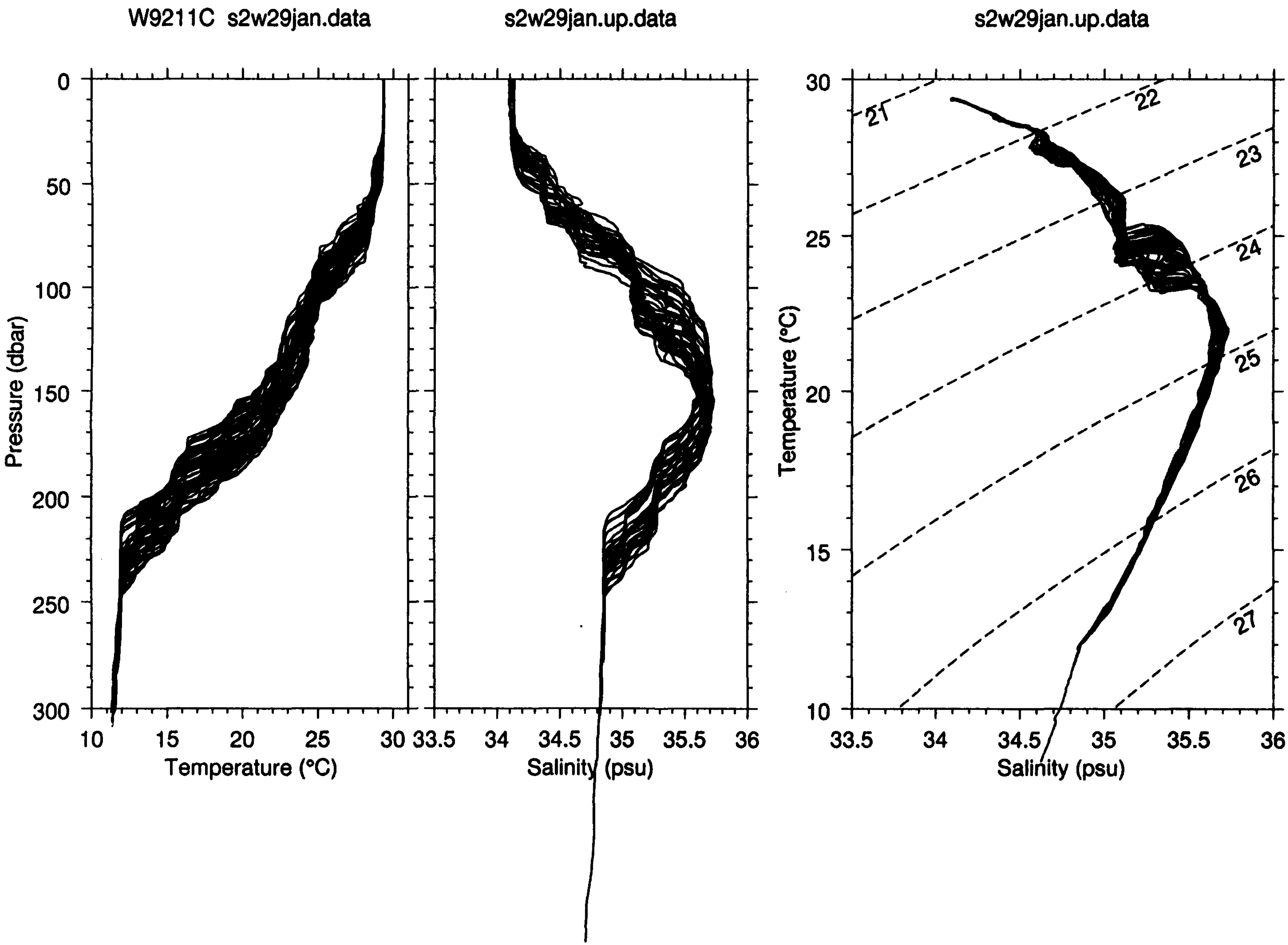
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Temperature (°C)
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Salinity (psu)
Temperature (°C)
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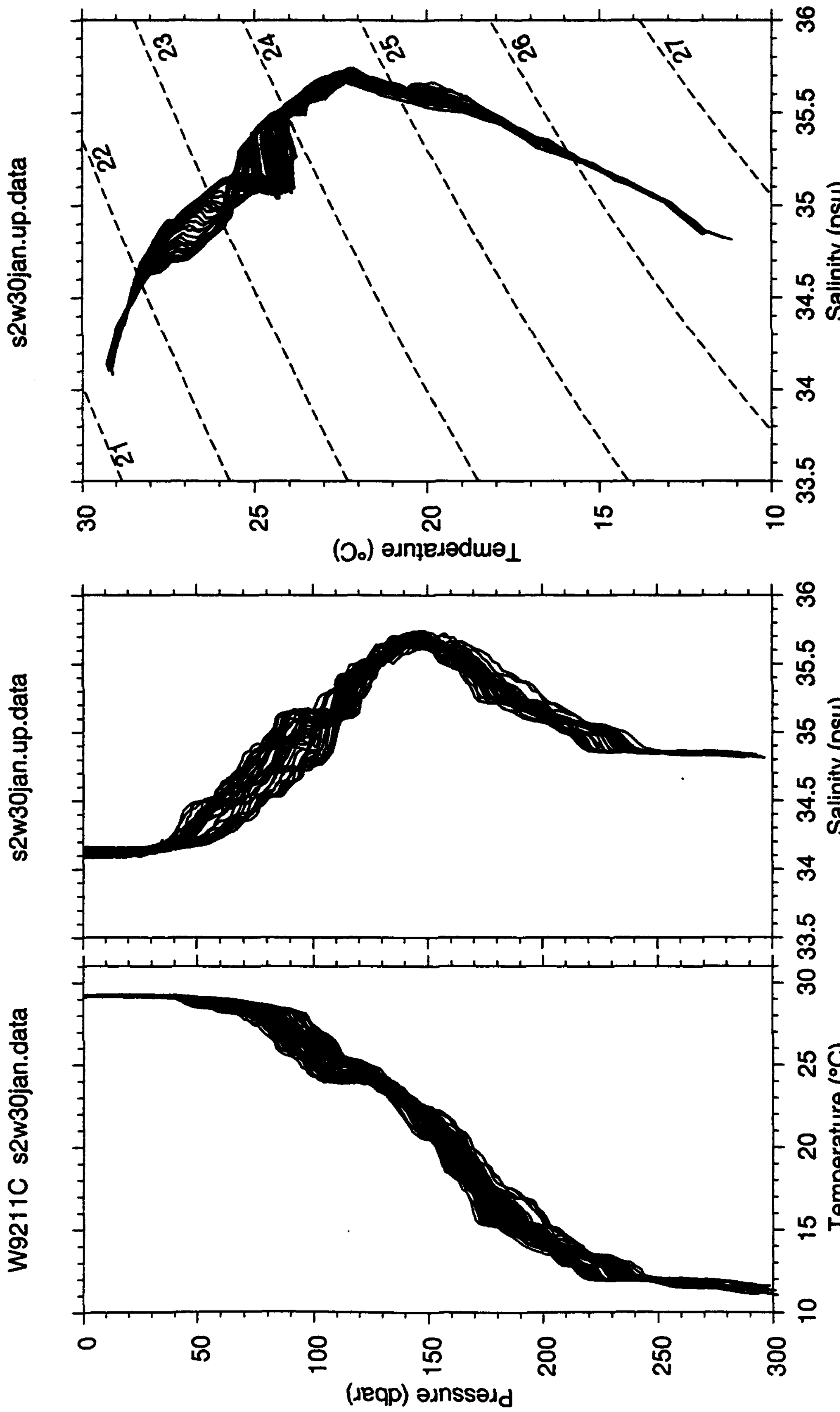
Salinity (psu)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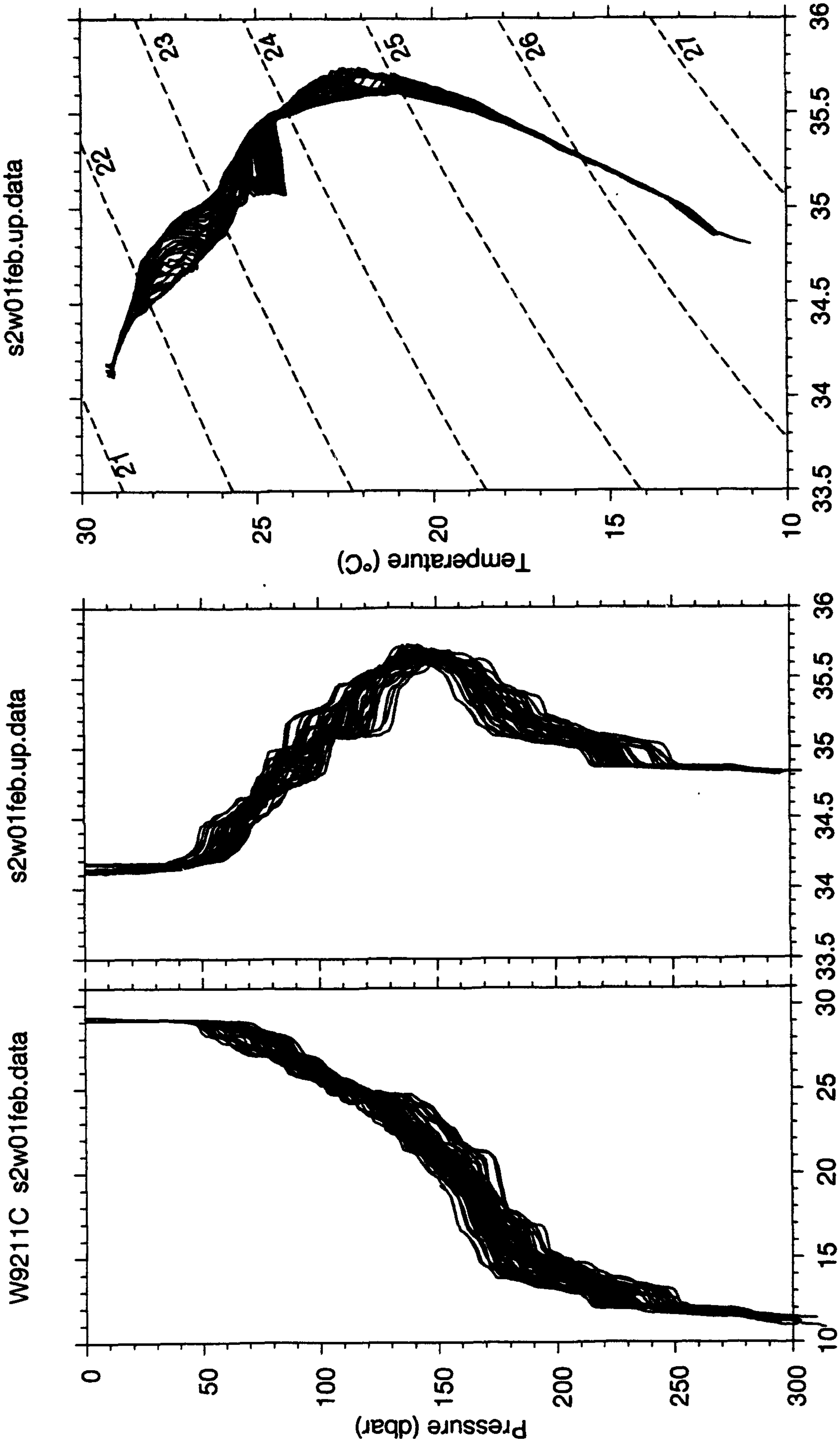
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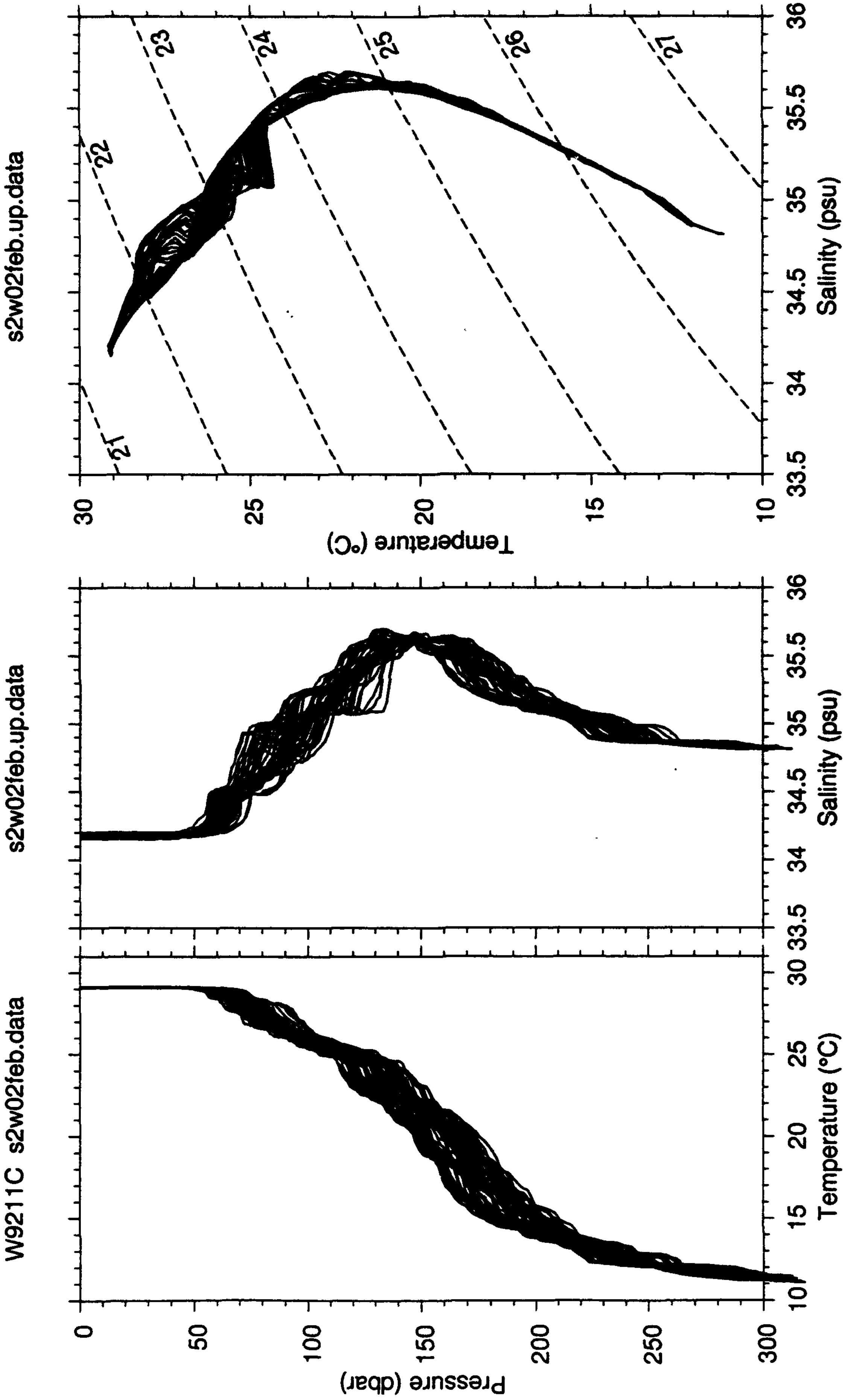
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Pressure (dbar)
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Temperature (°C)
Salinity (psu)
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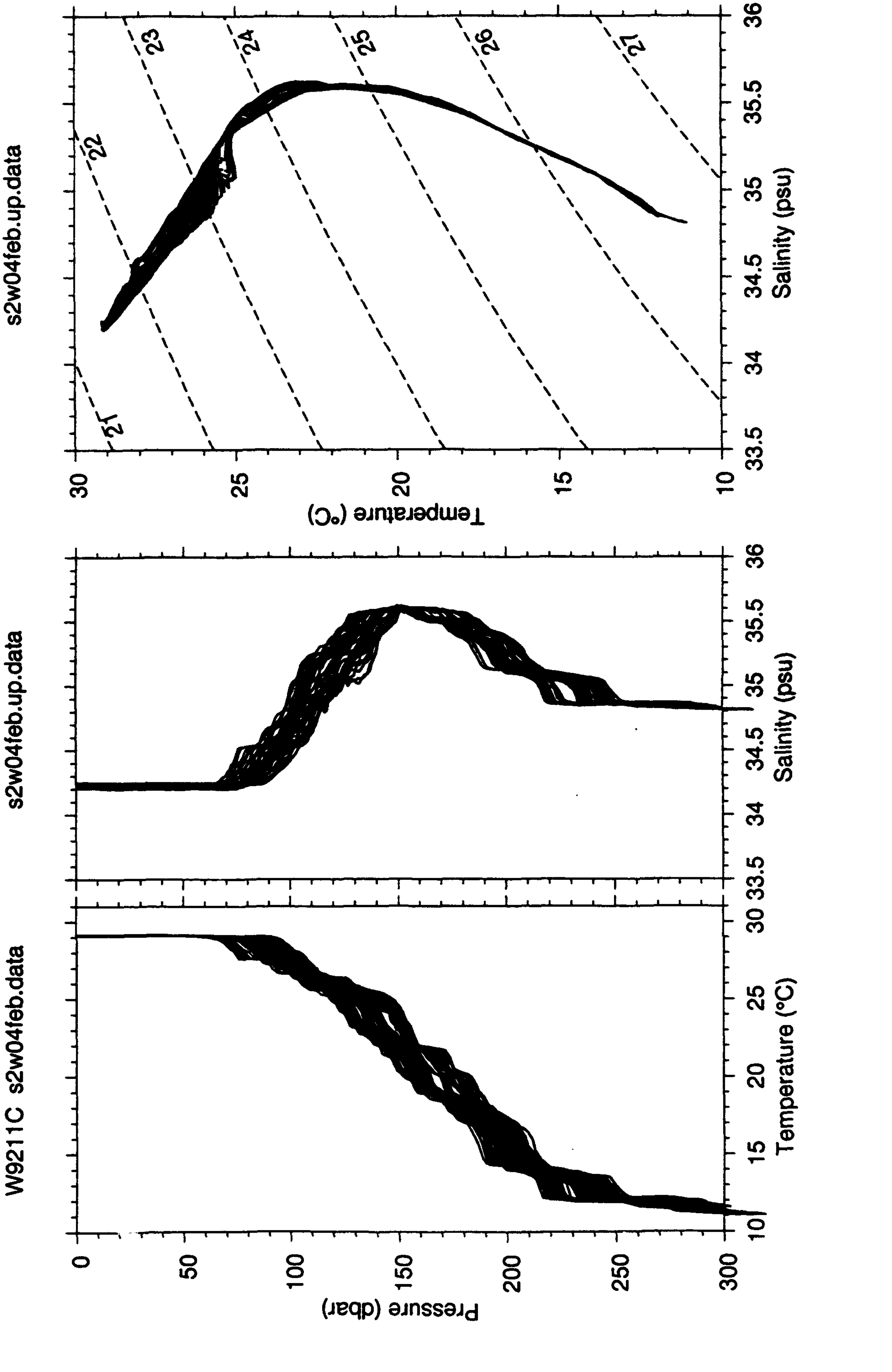

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Salinity (psu)
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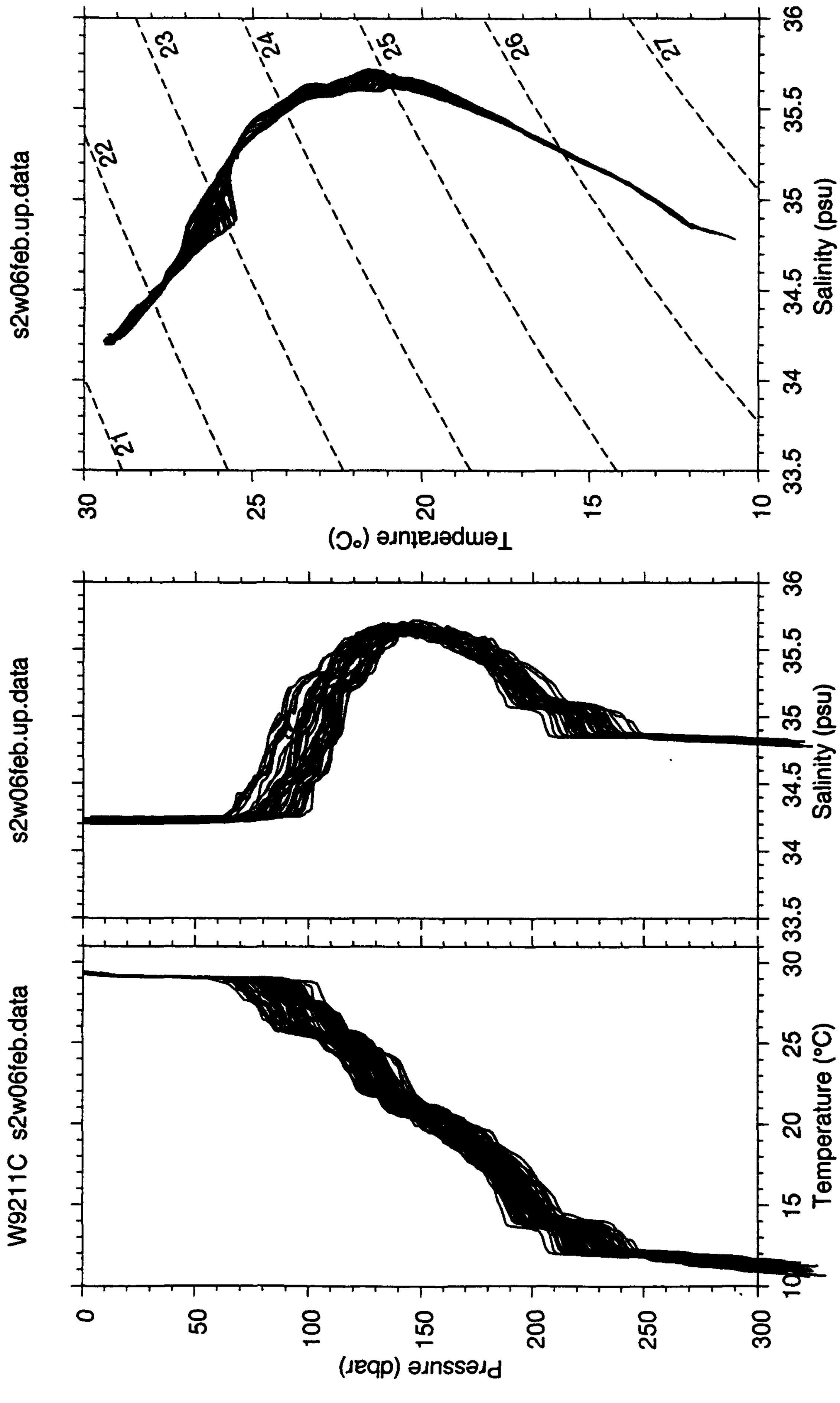
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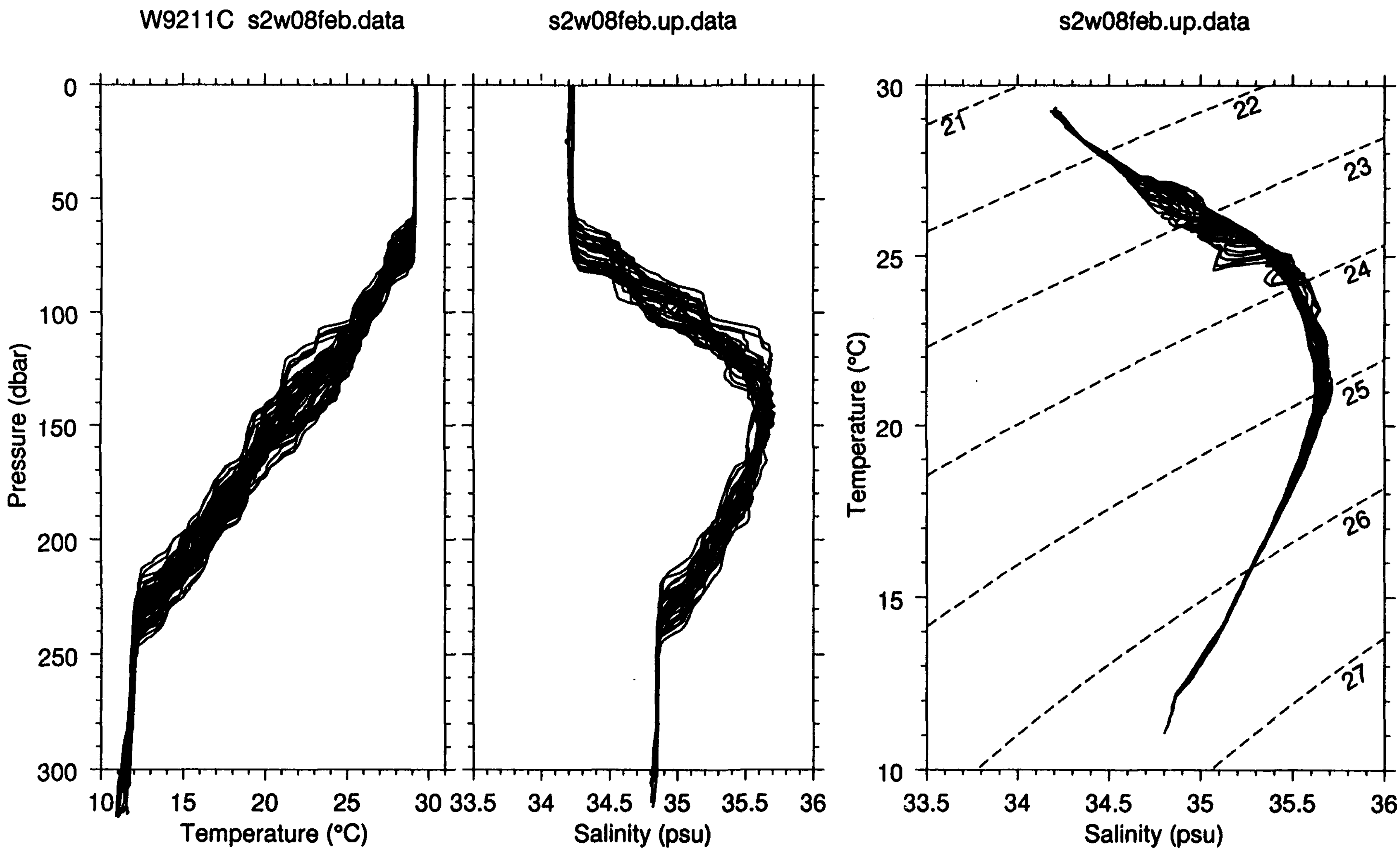

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Temperature (°C)
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Salinity (psu)
Temperature (°C)
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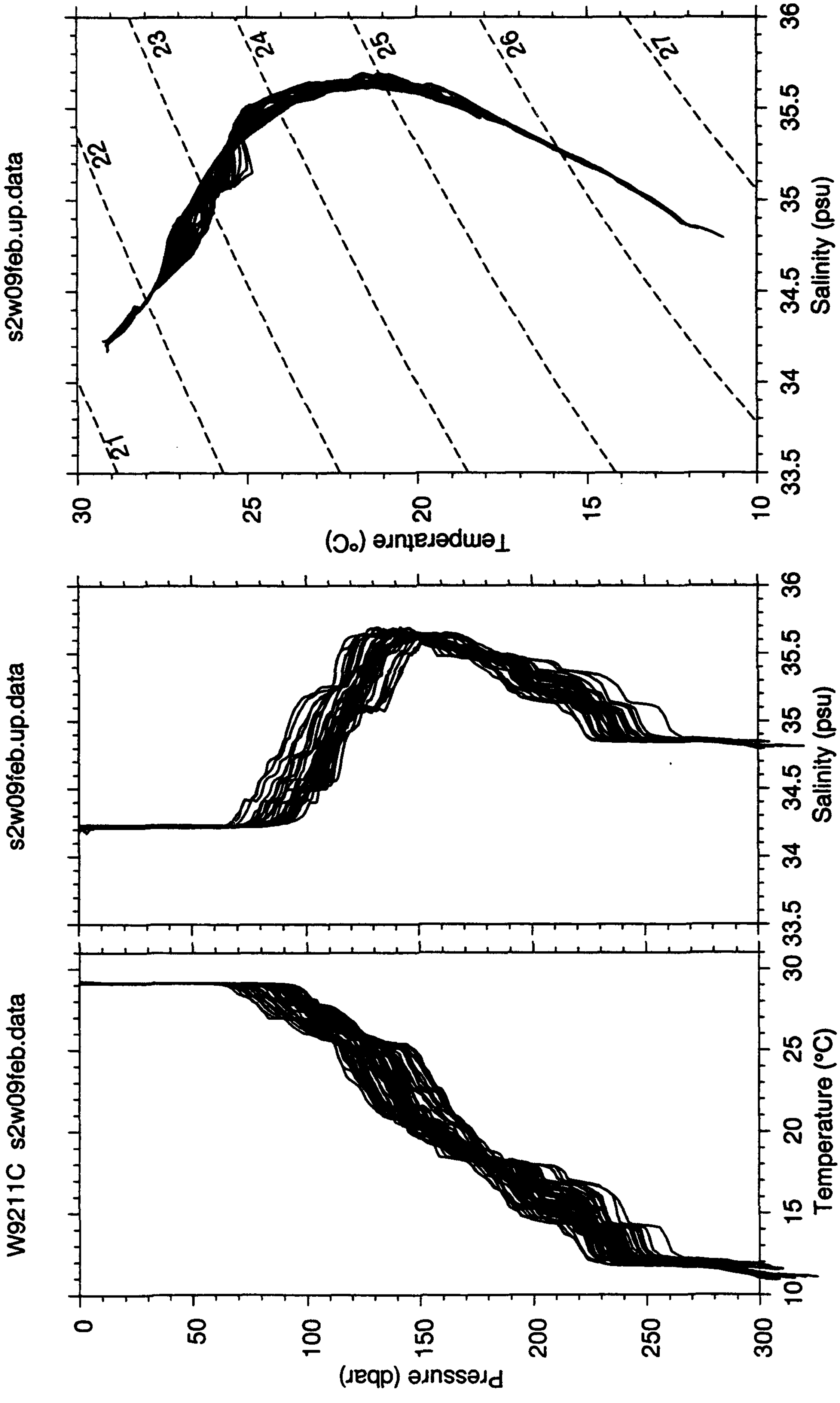
Salinity (psu)



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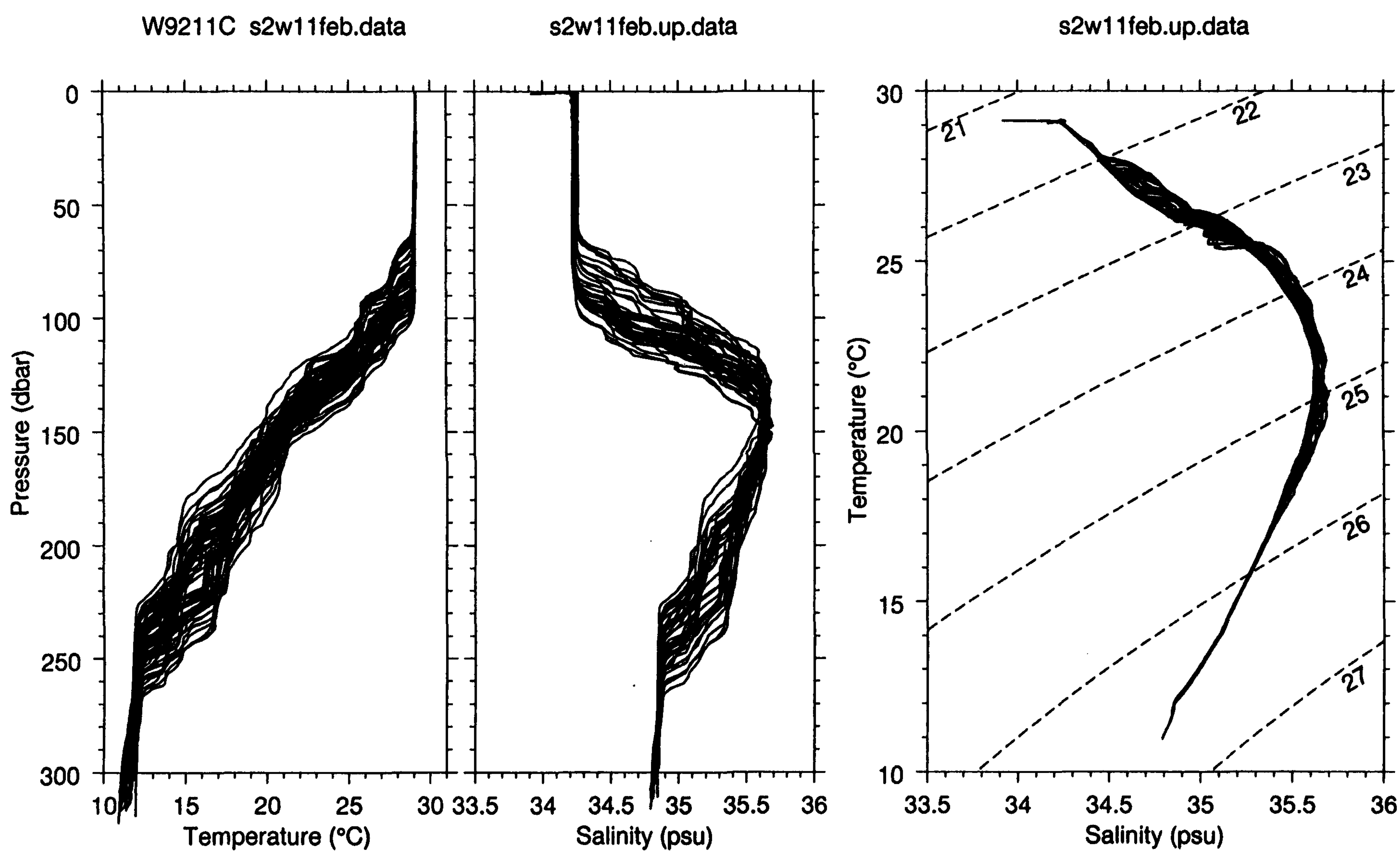
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Temperature (°C)
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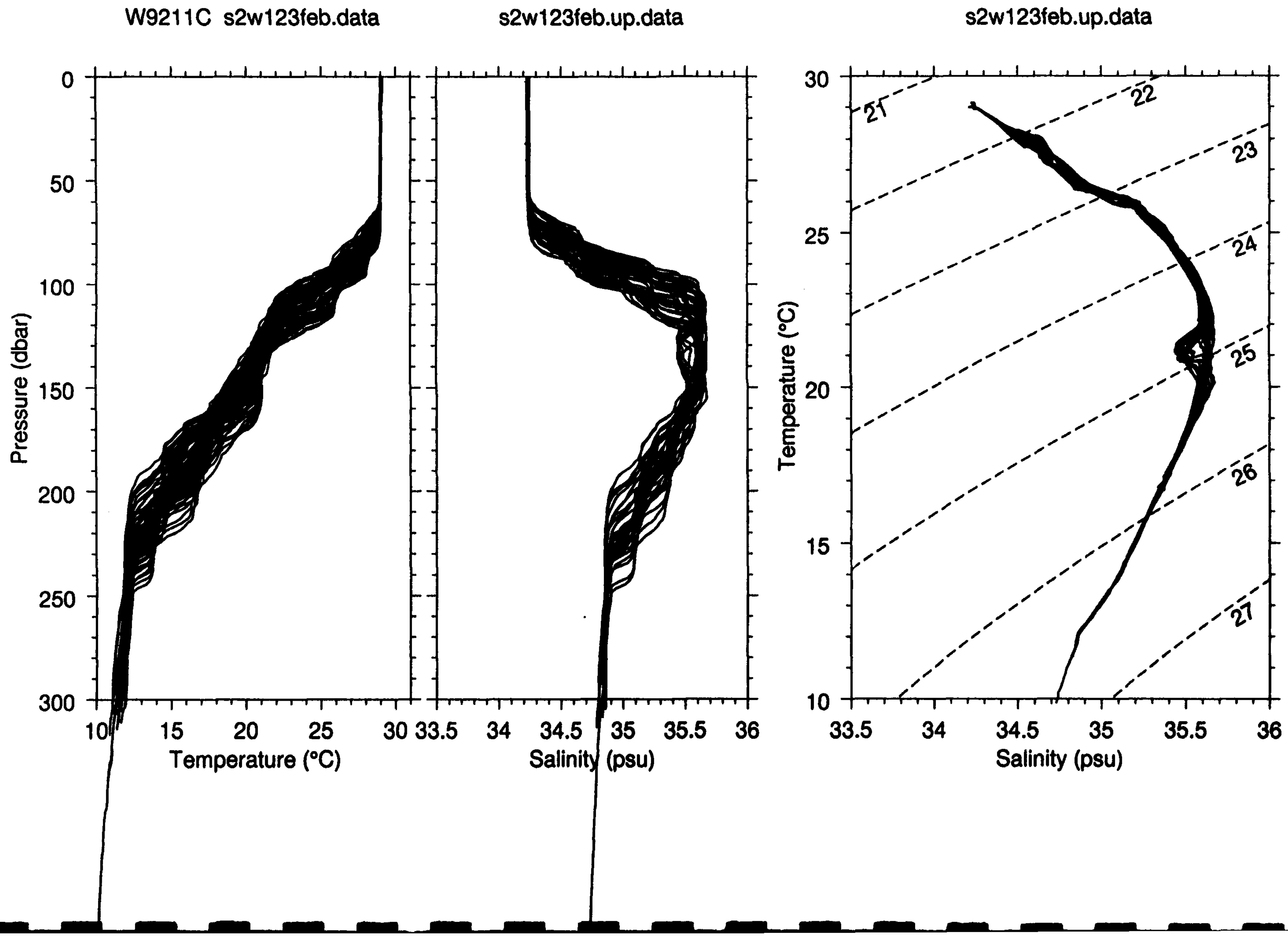
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Salinity (psu)
Temperature (°C)
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Salinity (psu)
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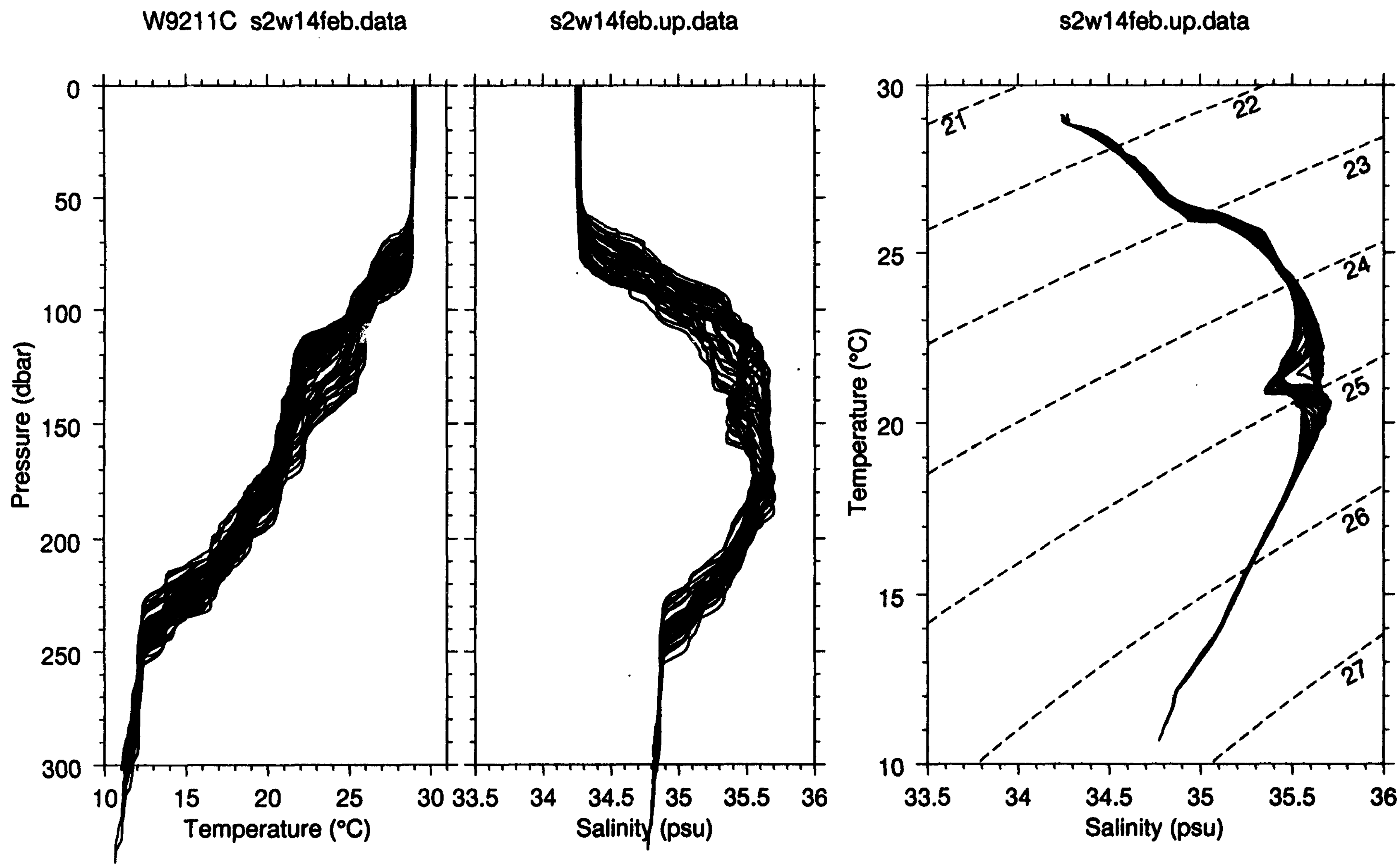
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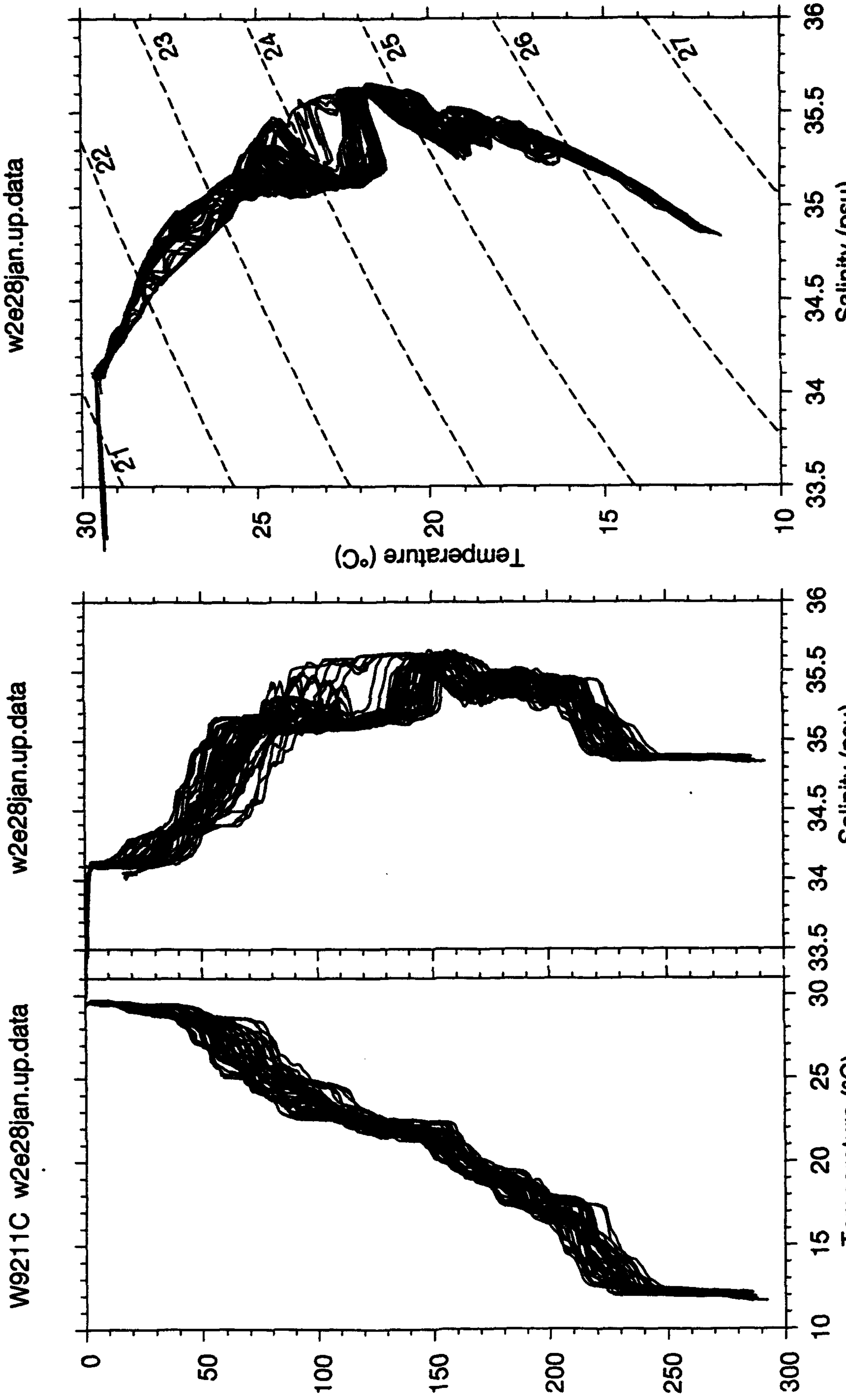
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Salinity (psu)
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Temperature (°C)
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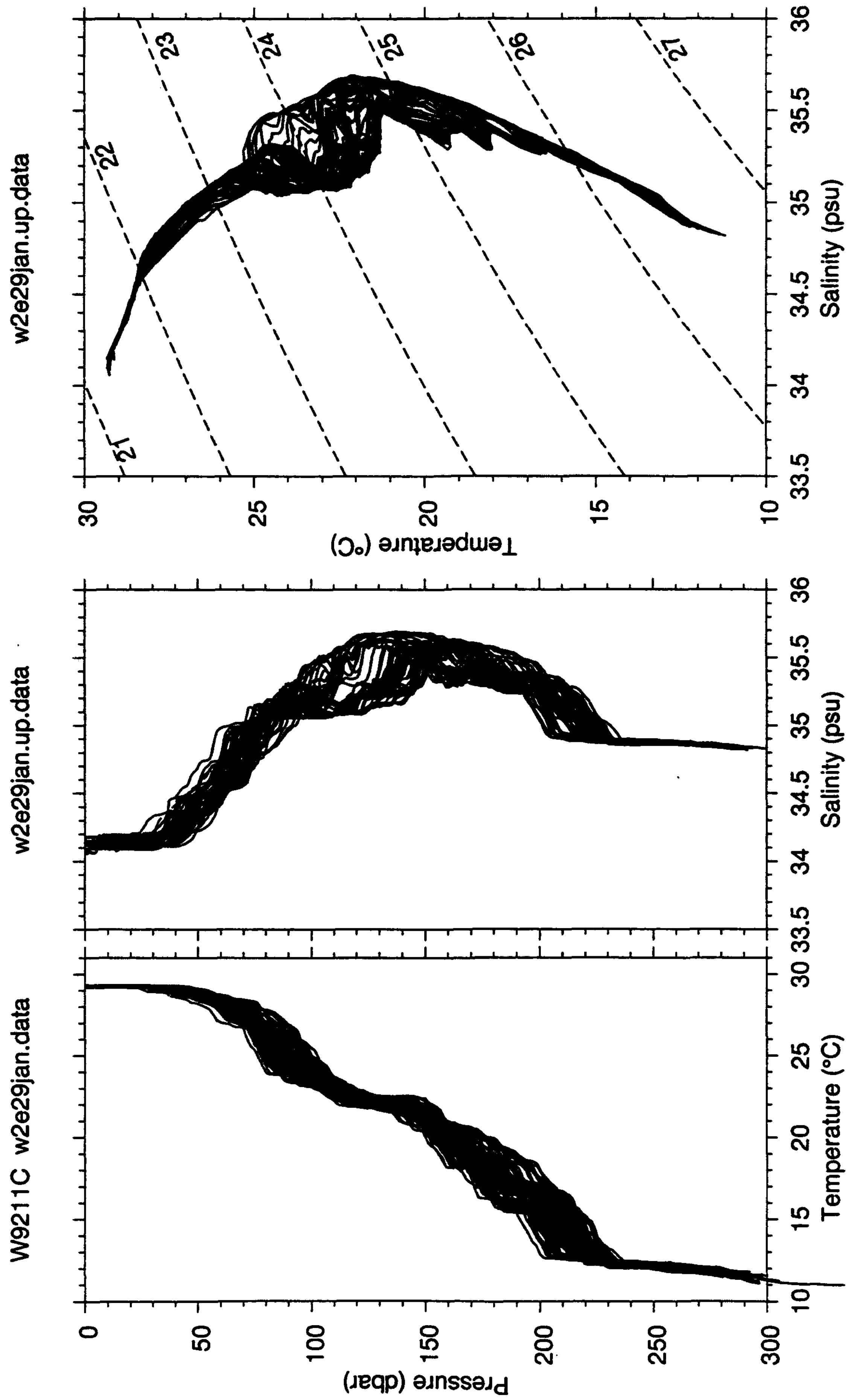
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Salinity (psu)
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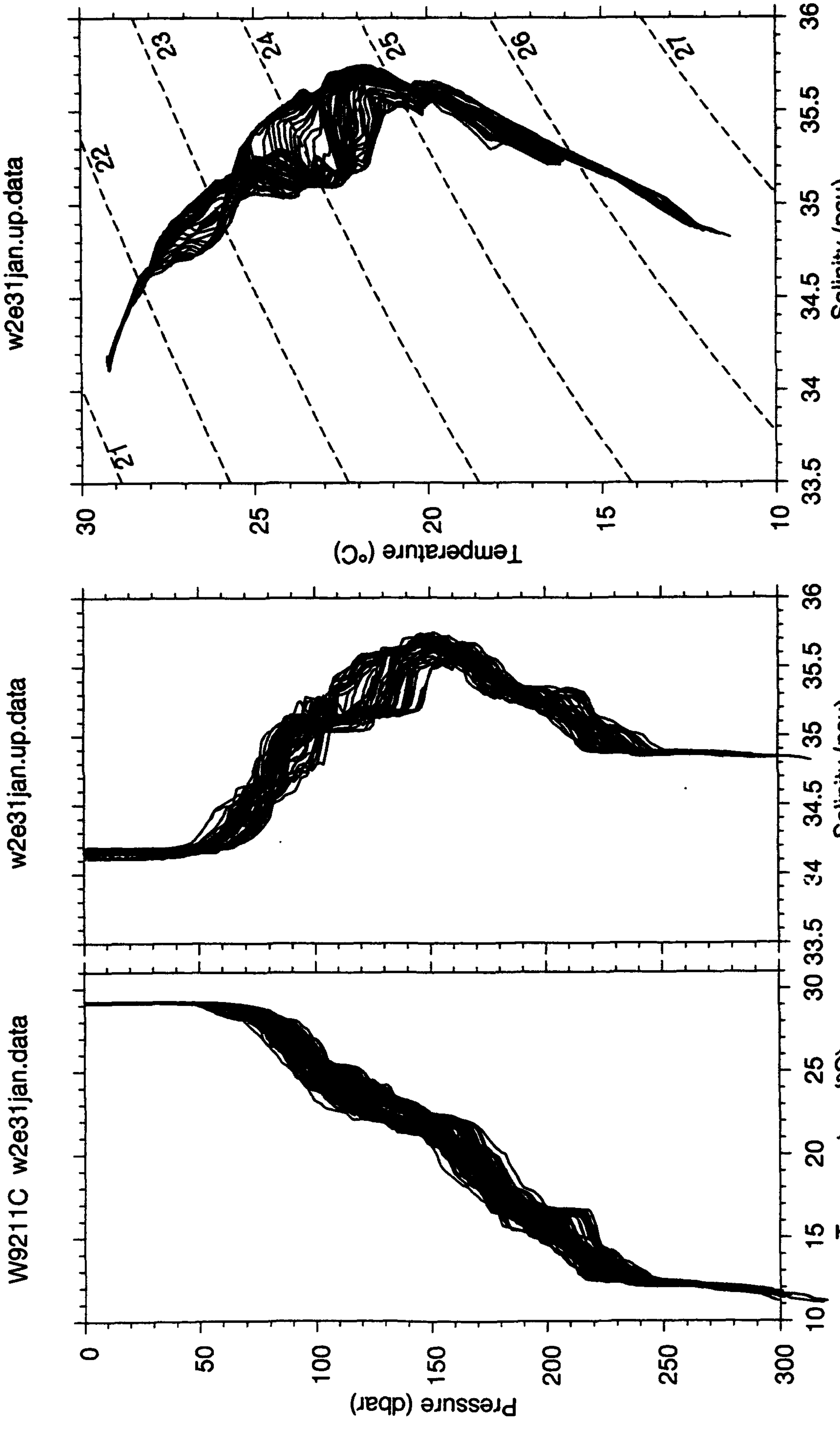
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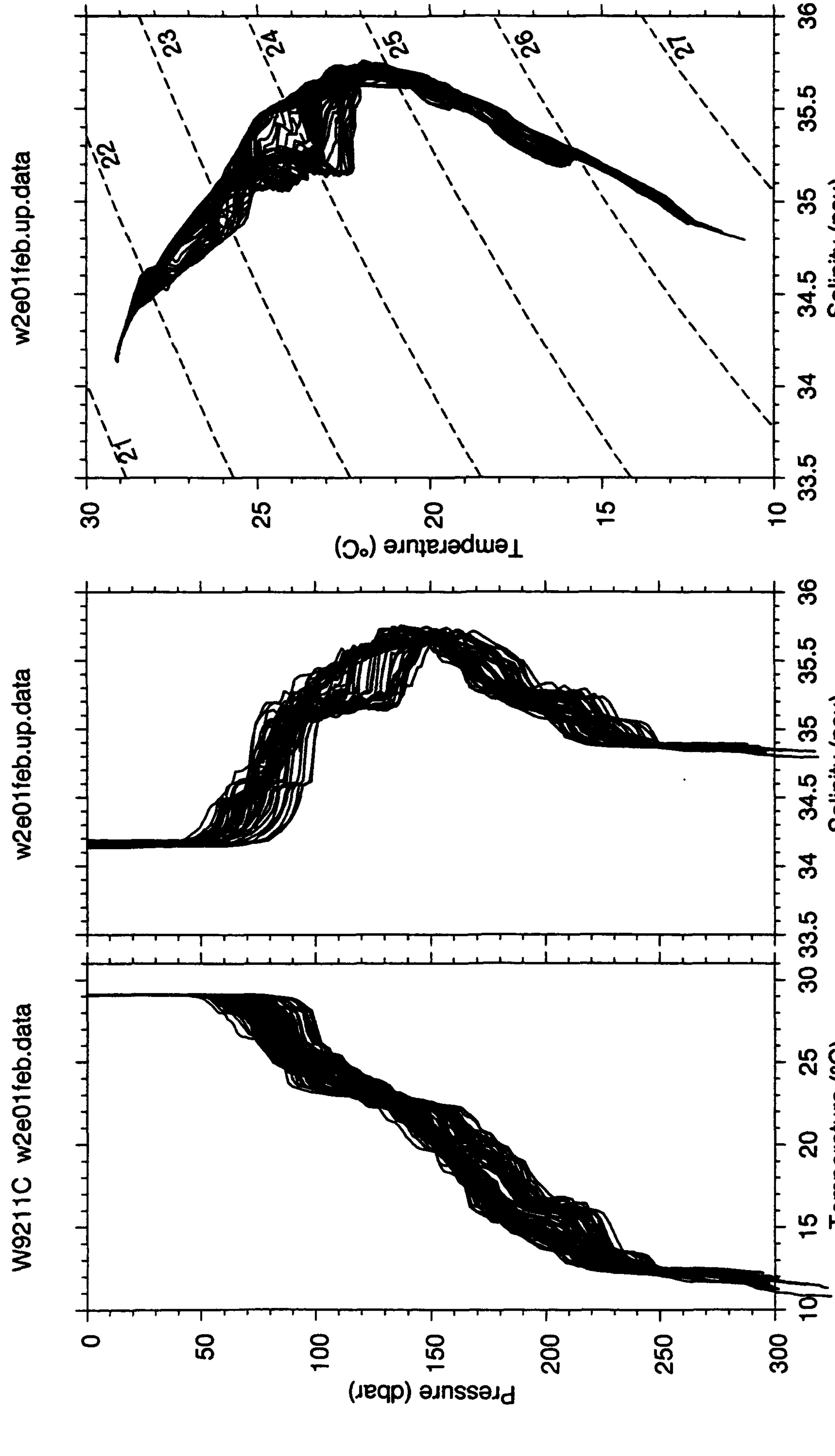
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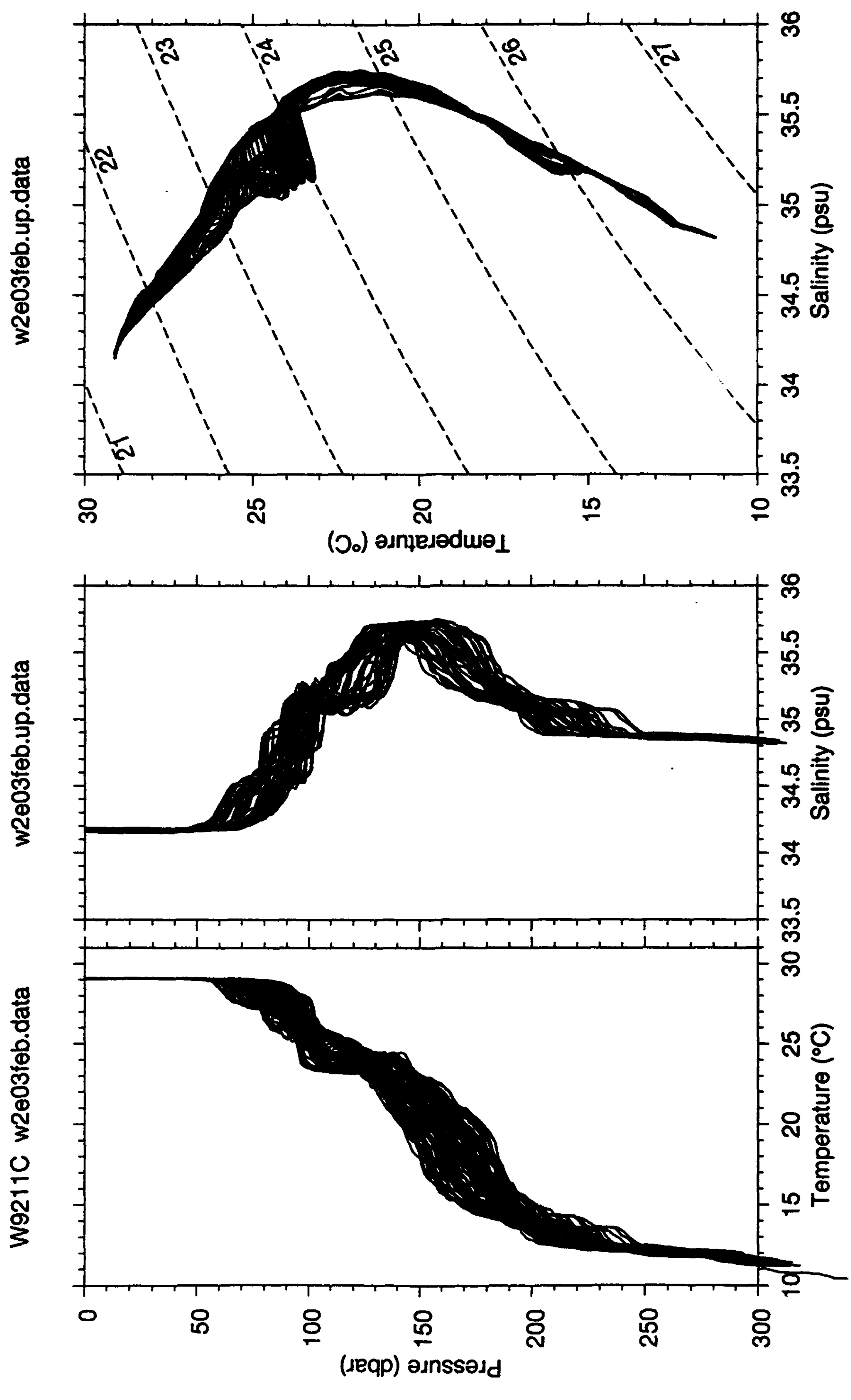
Temperature (°C)
Salinity (psu)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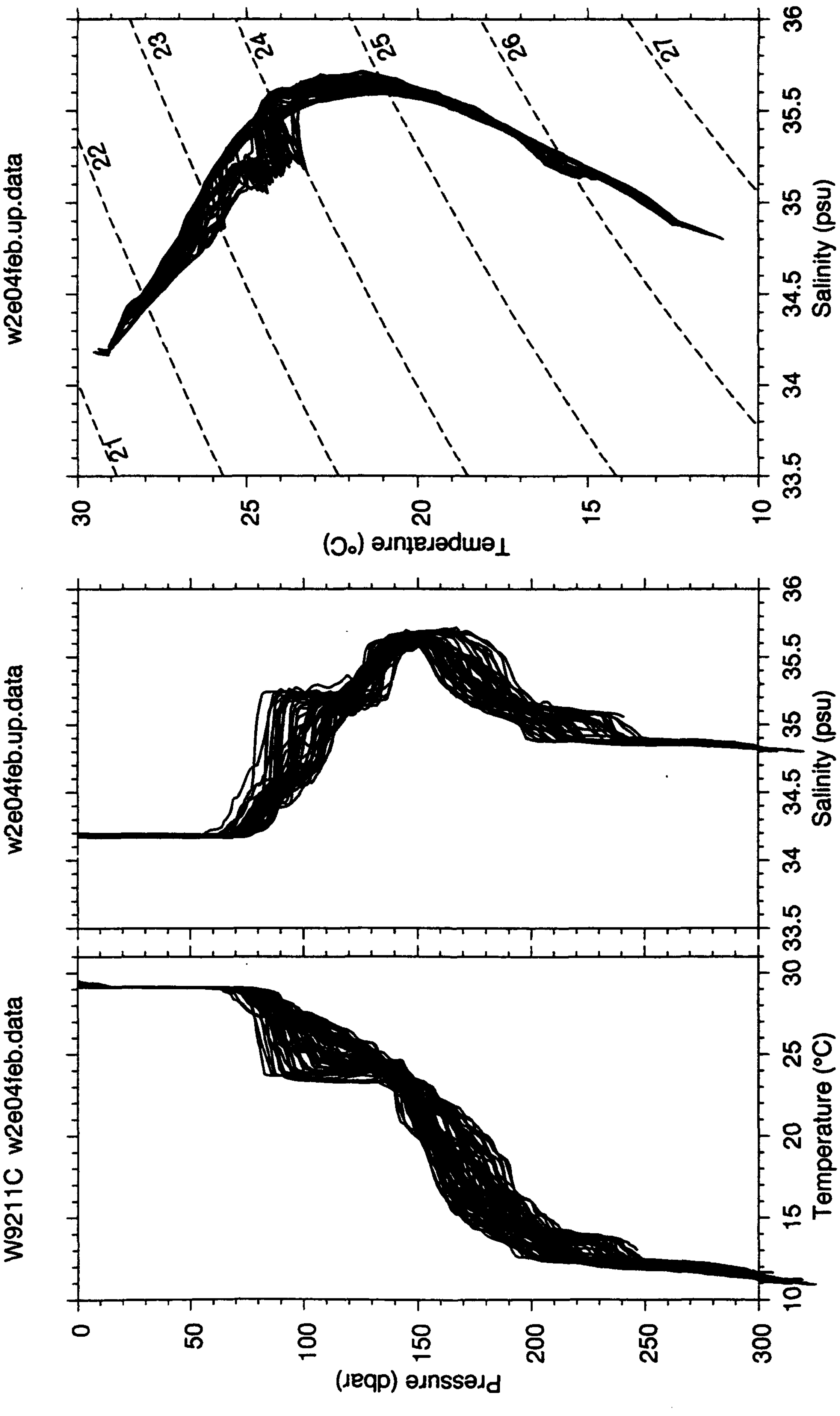
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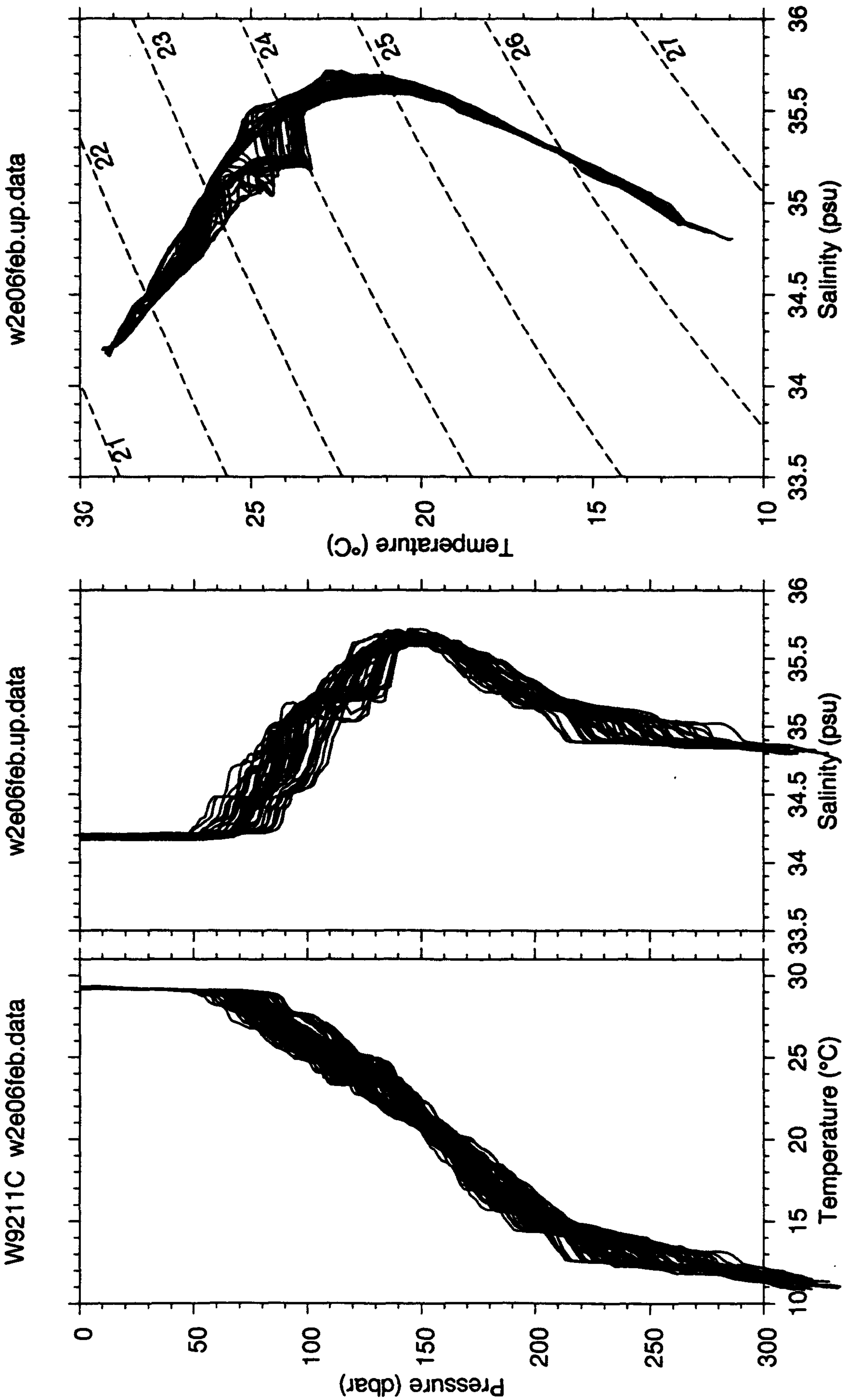
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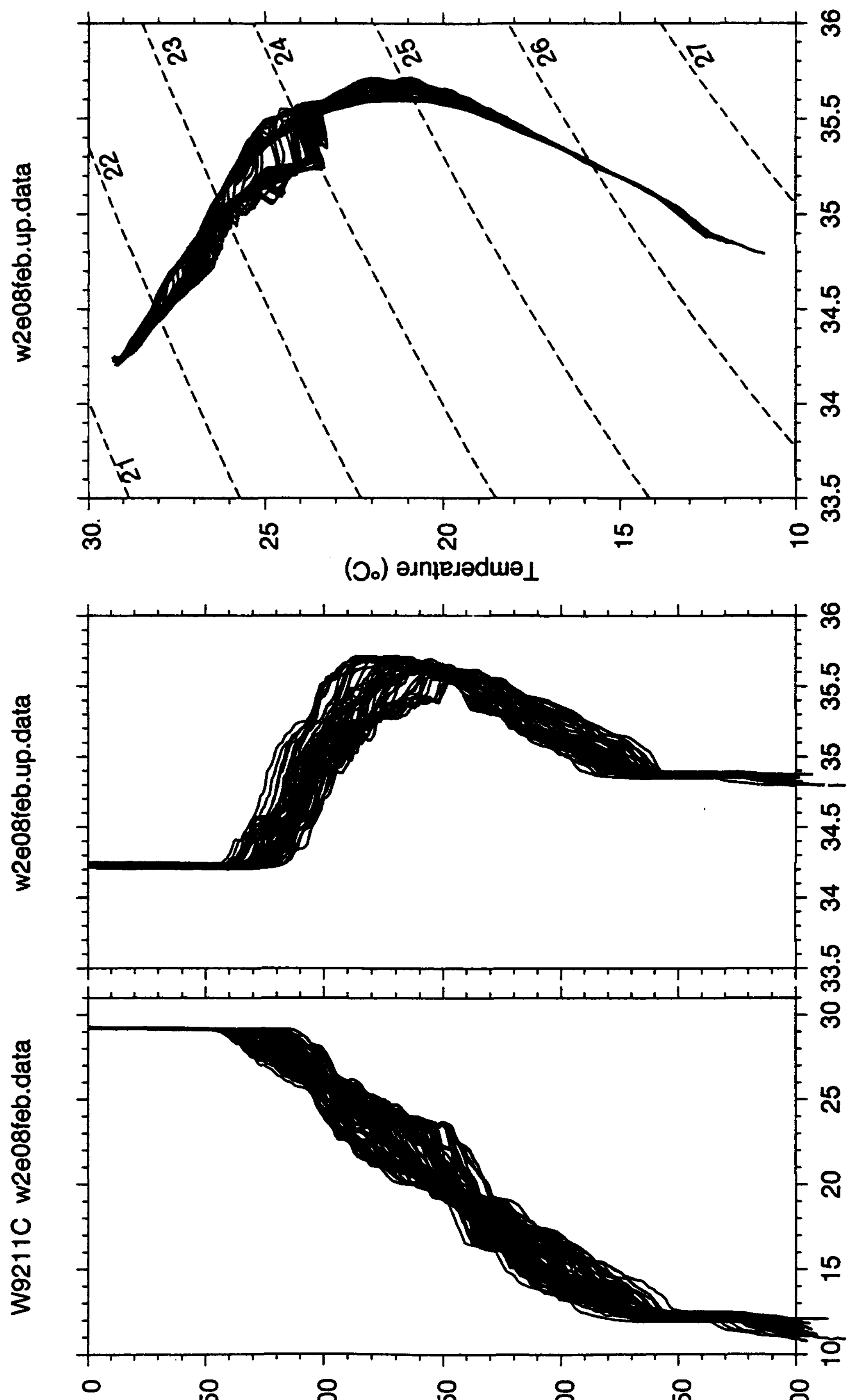
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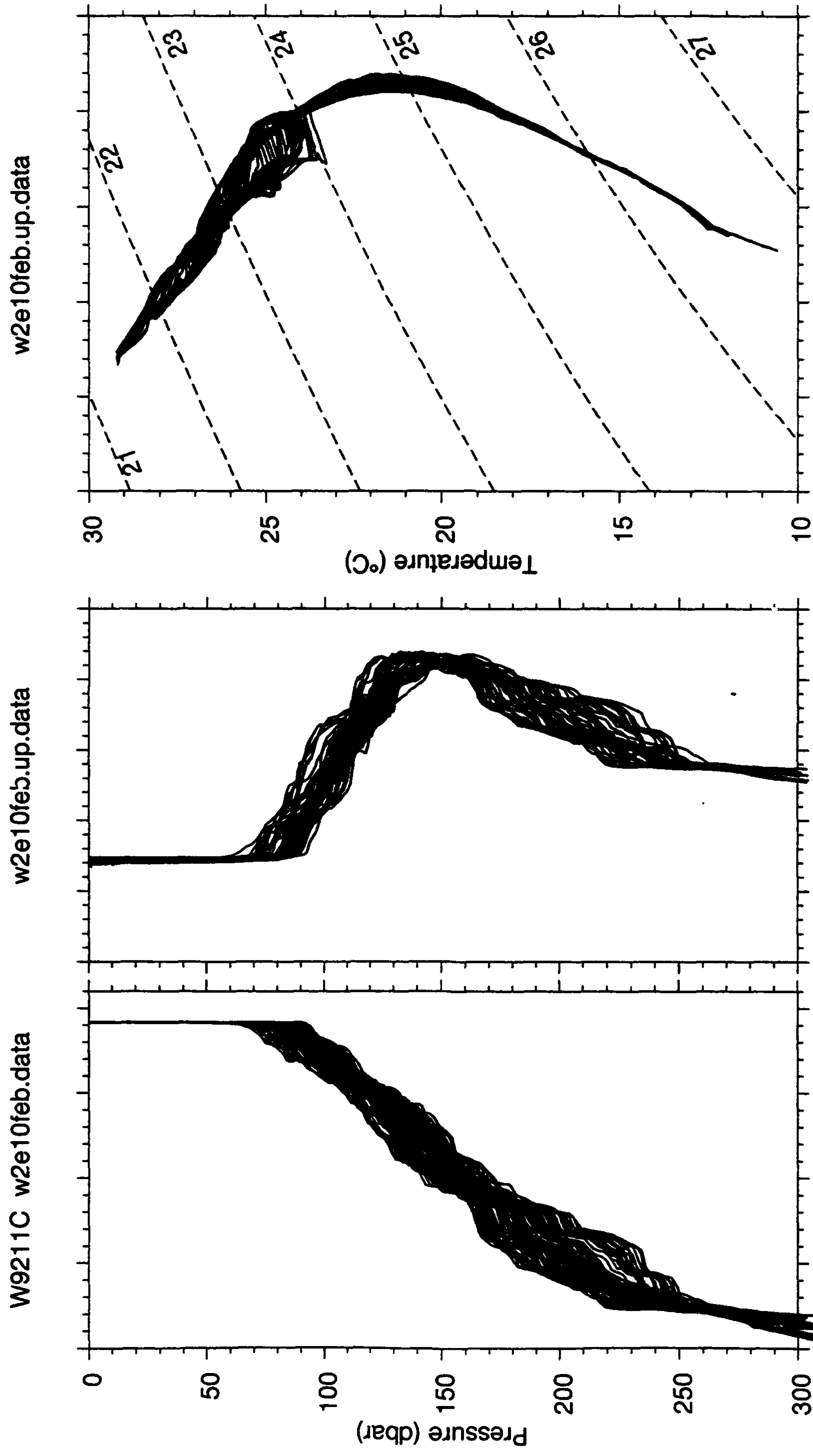
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Salinity (psu)
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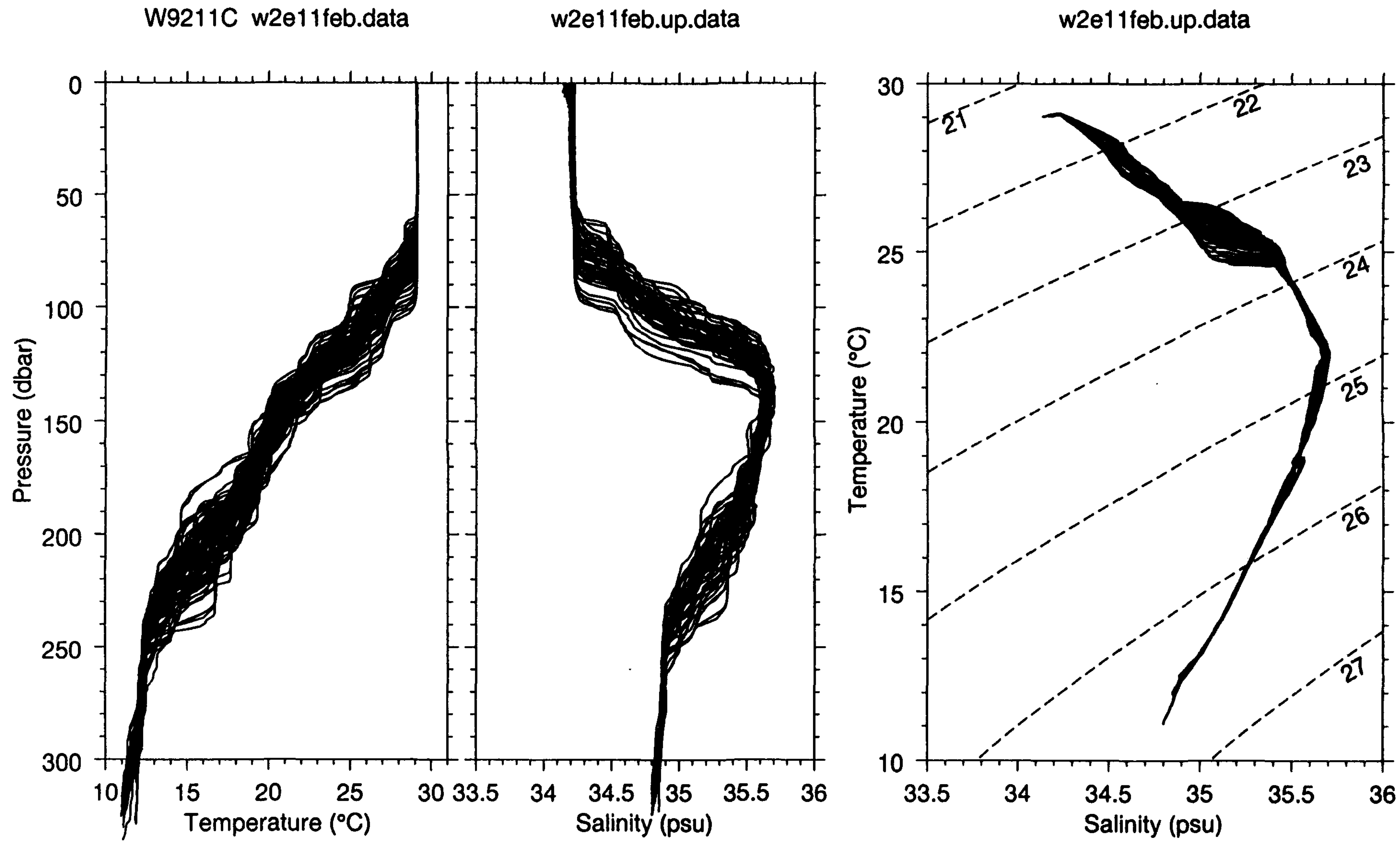
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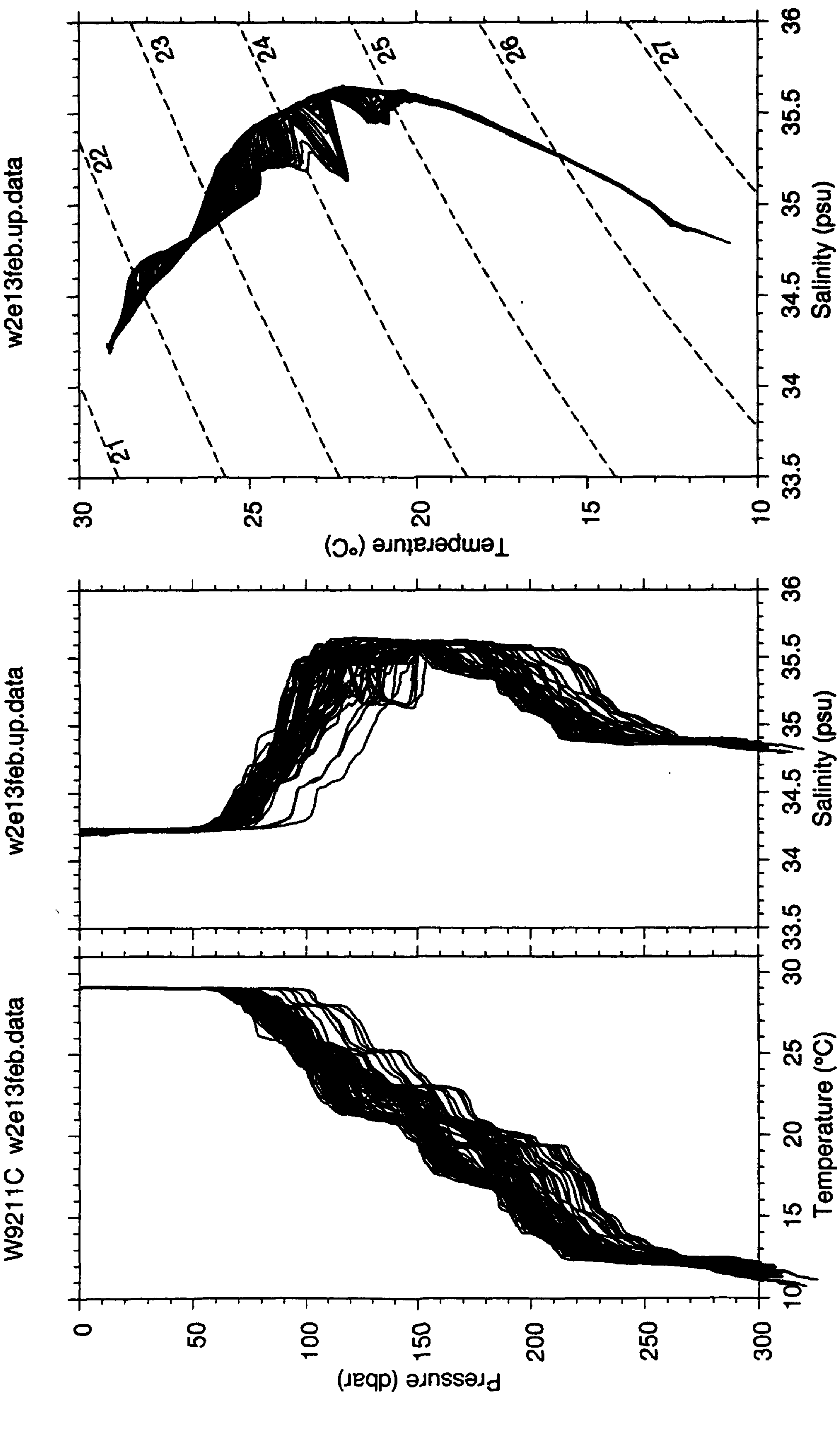

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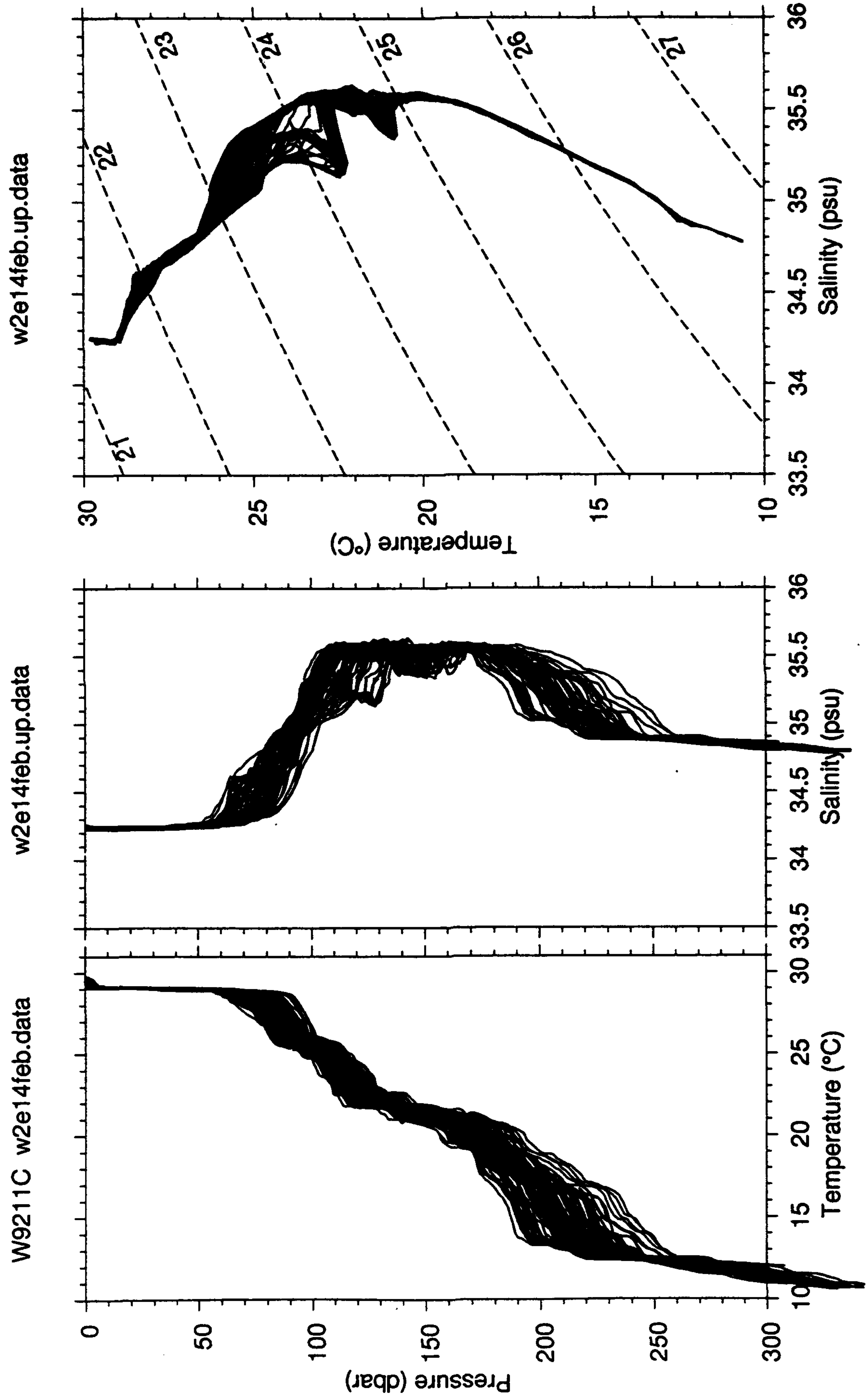

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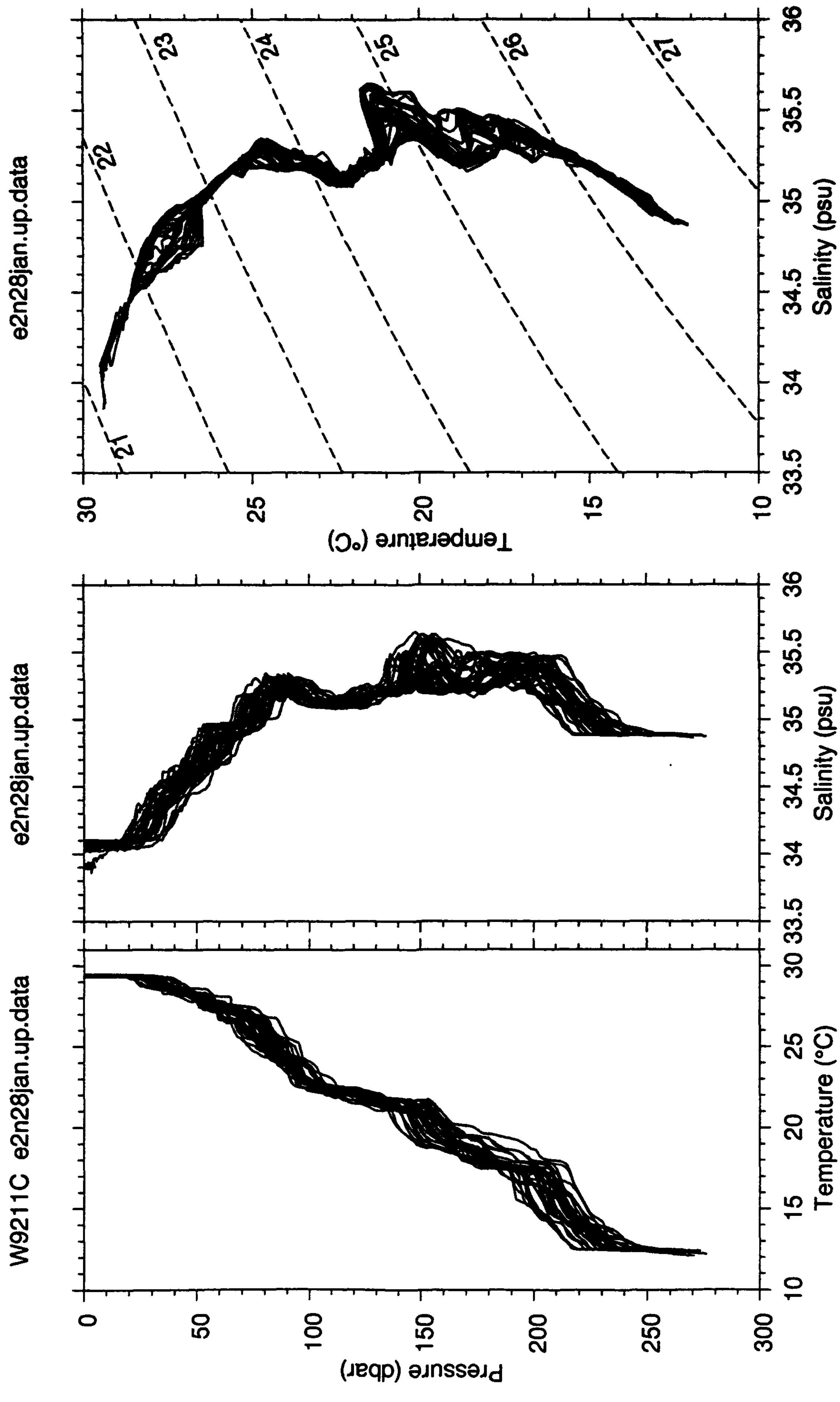

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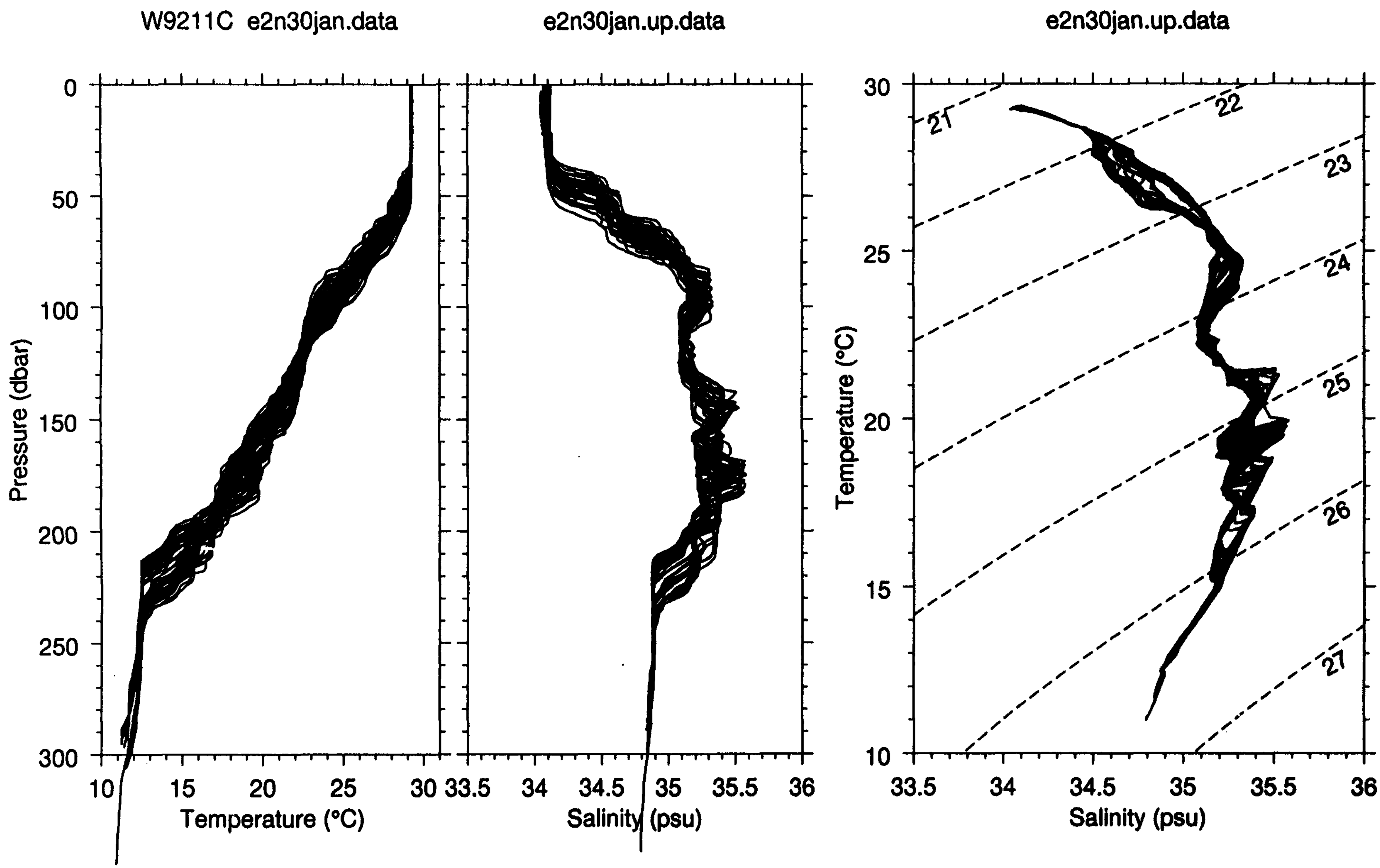

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Temperature (°C)
Salinity (psu)
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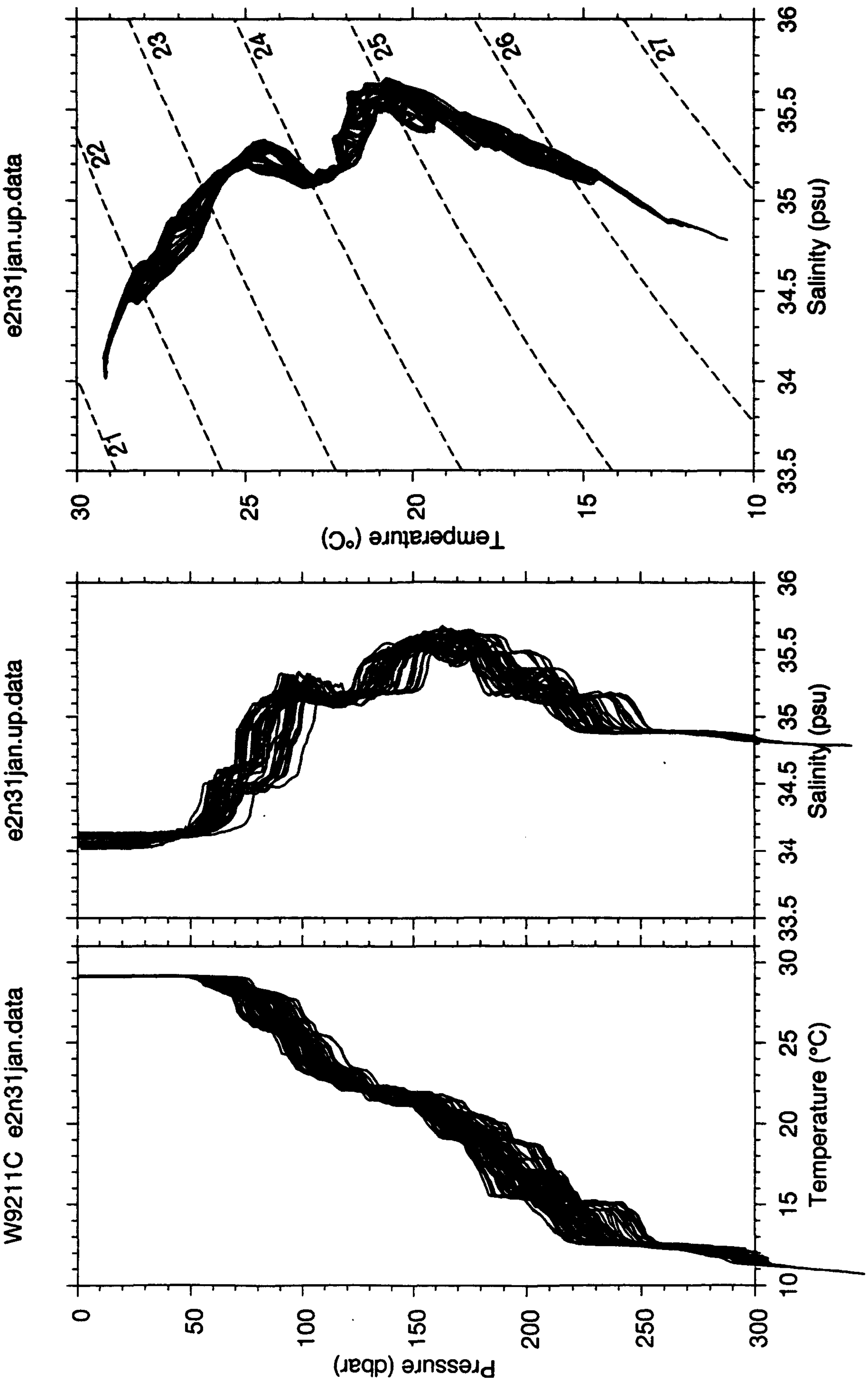
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Temperature (°C)
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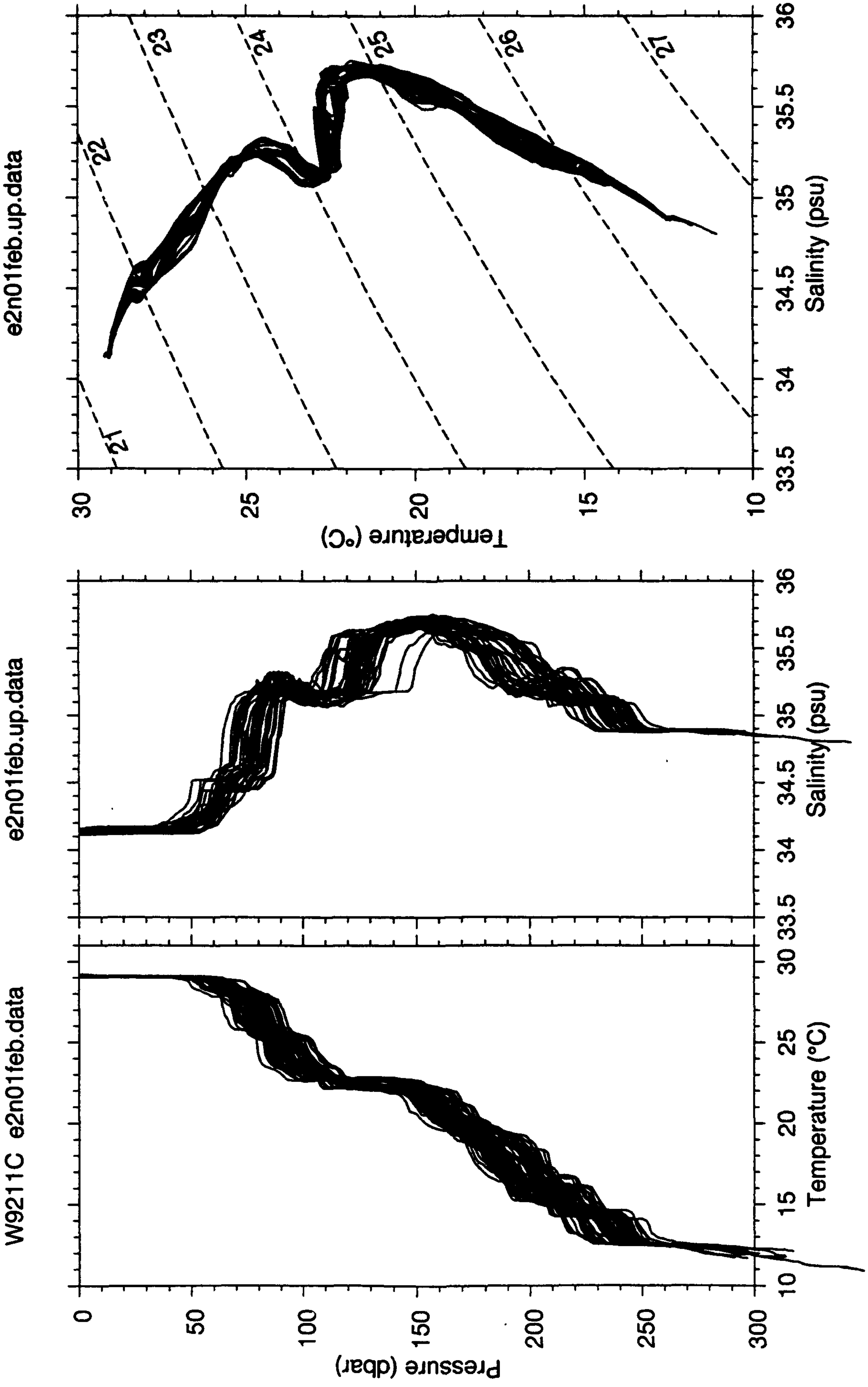
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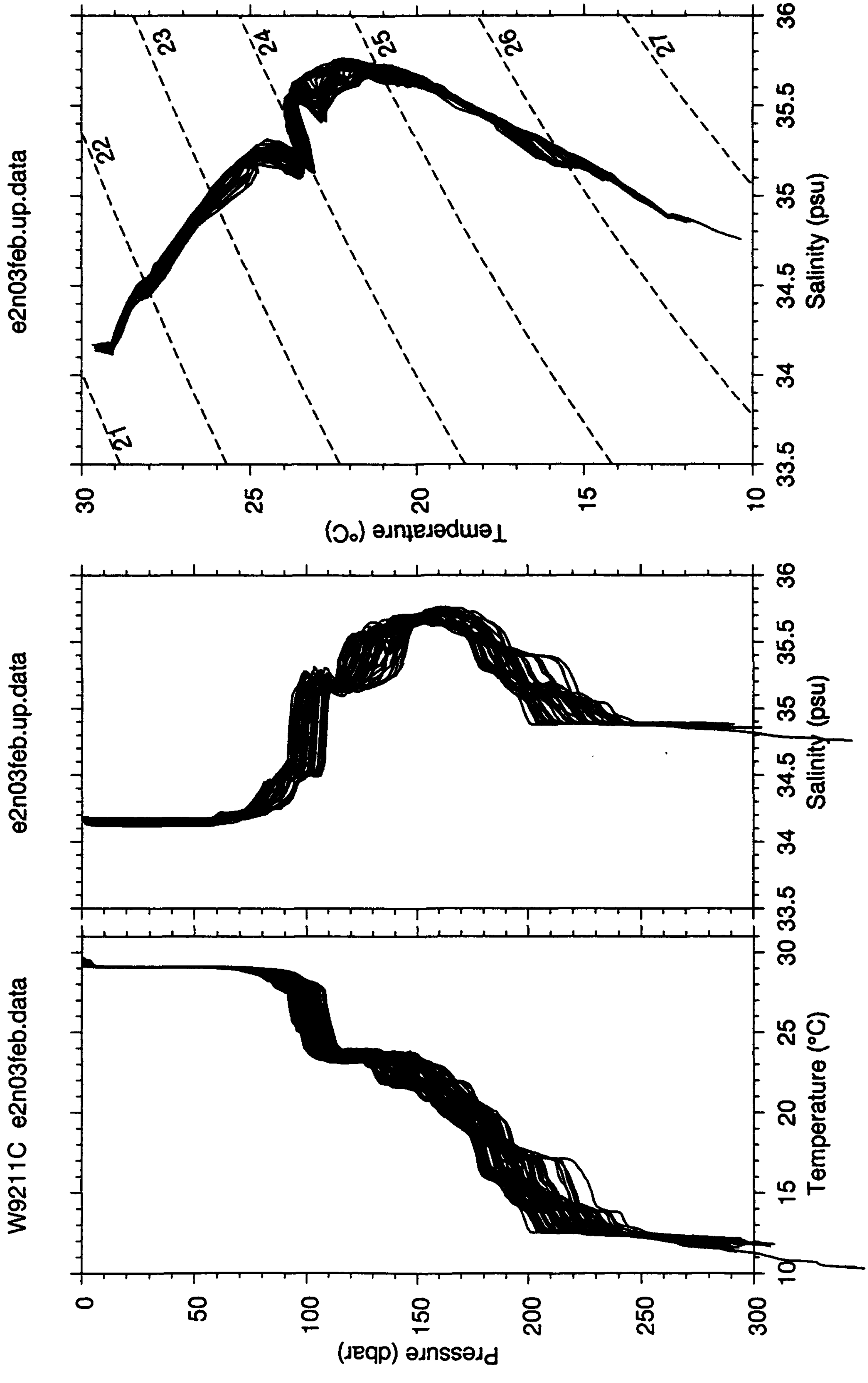
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Temperature (°C)
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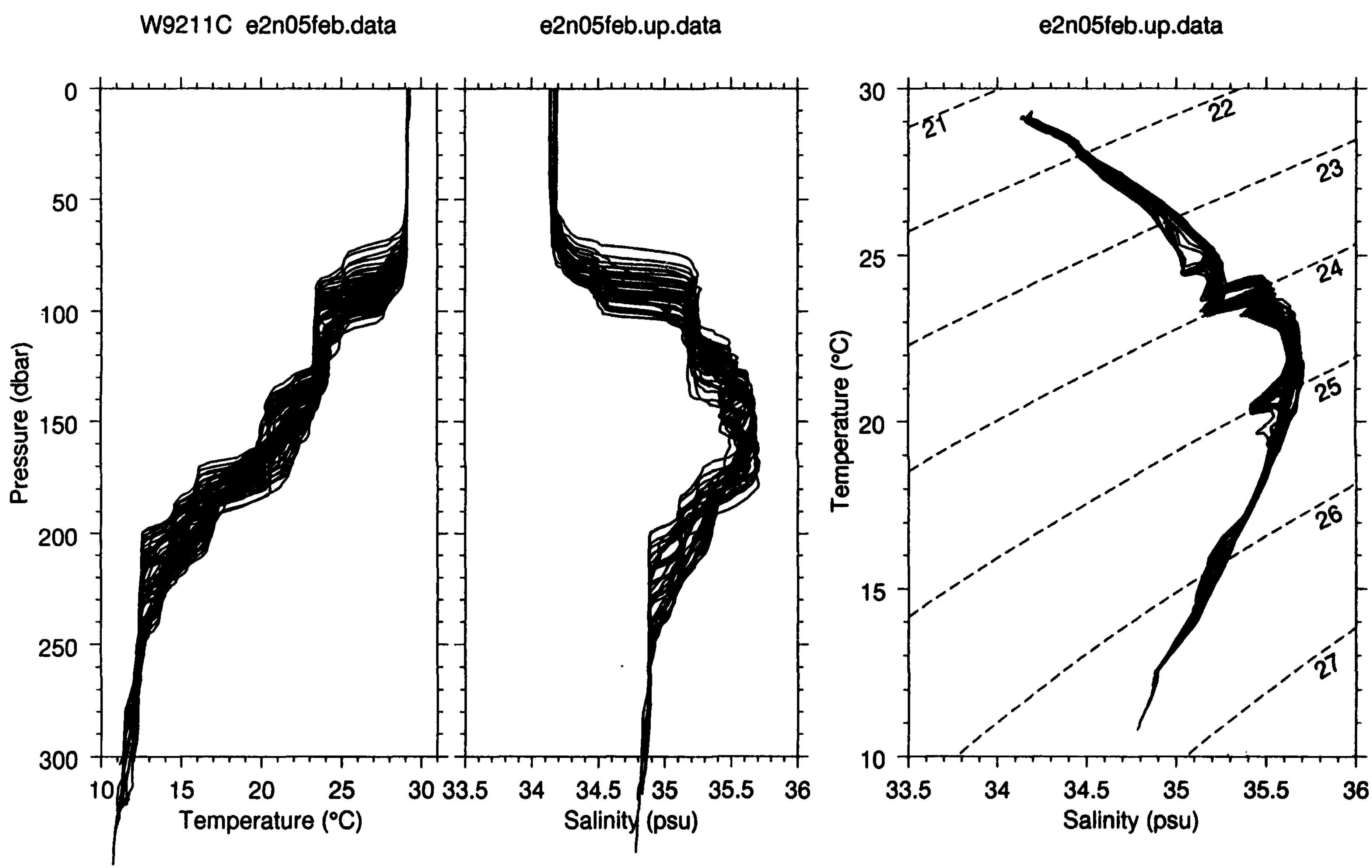

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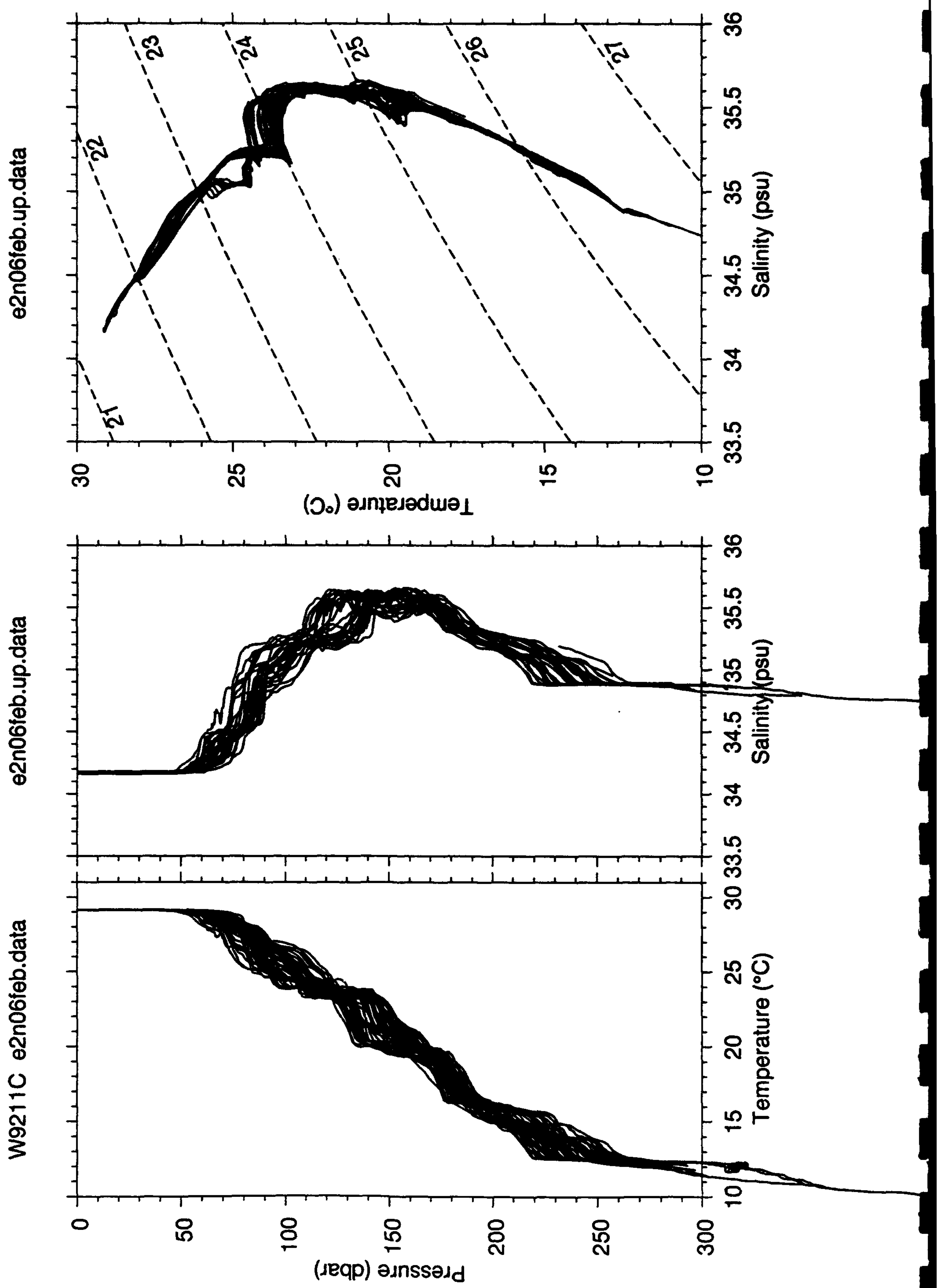
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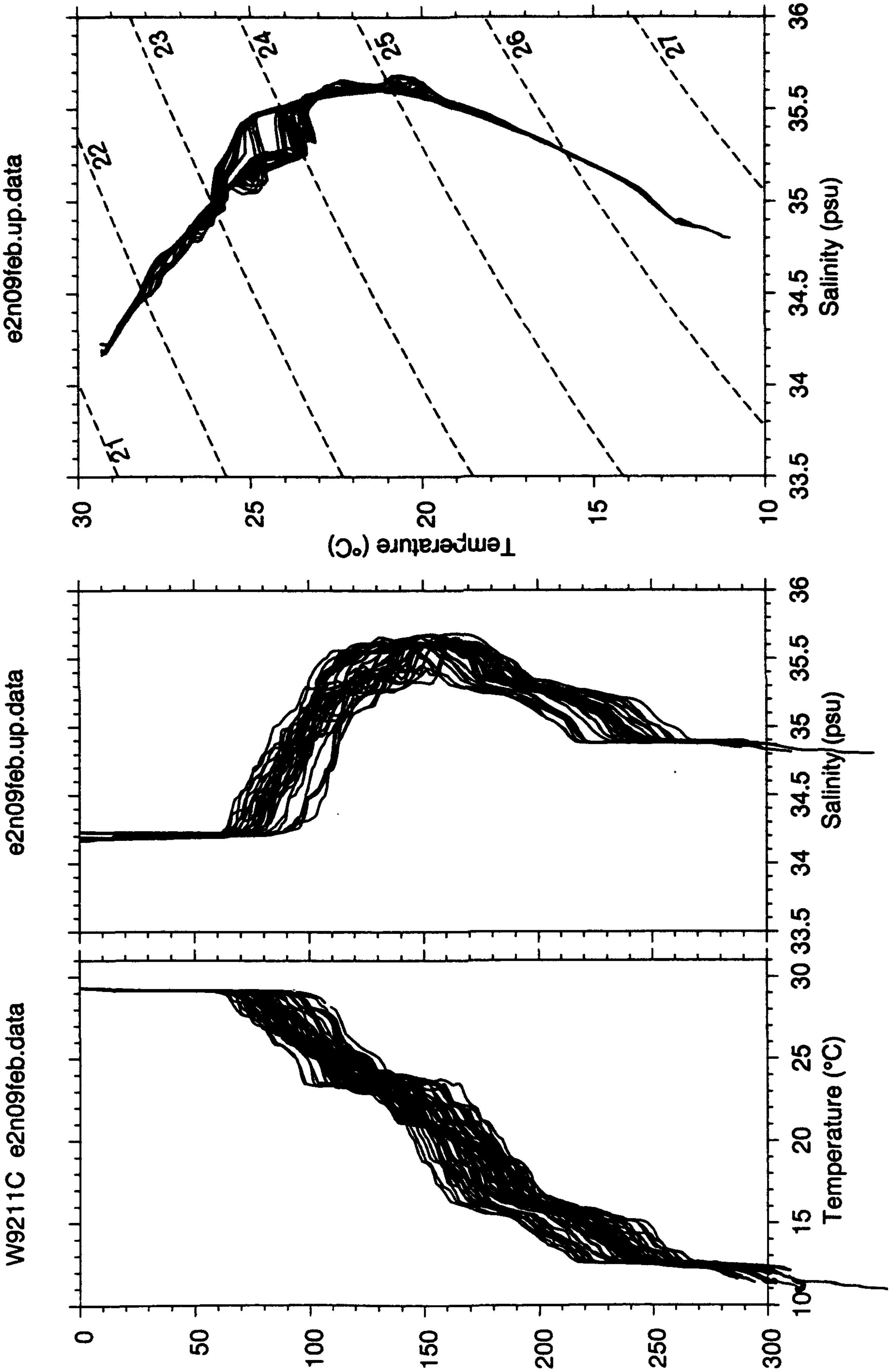
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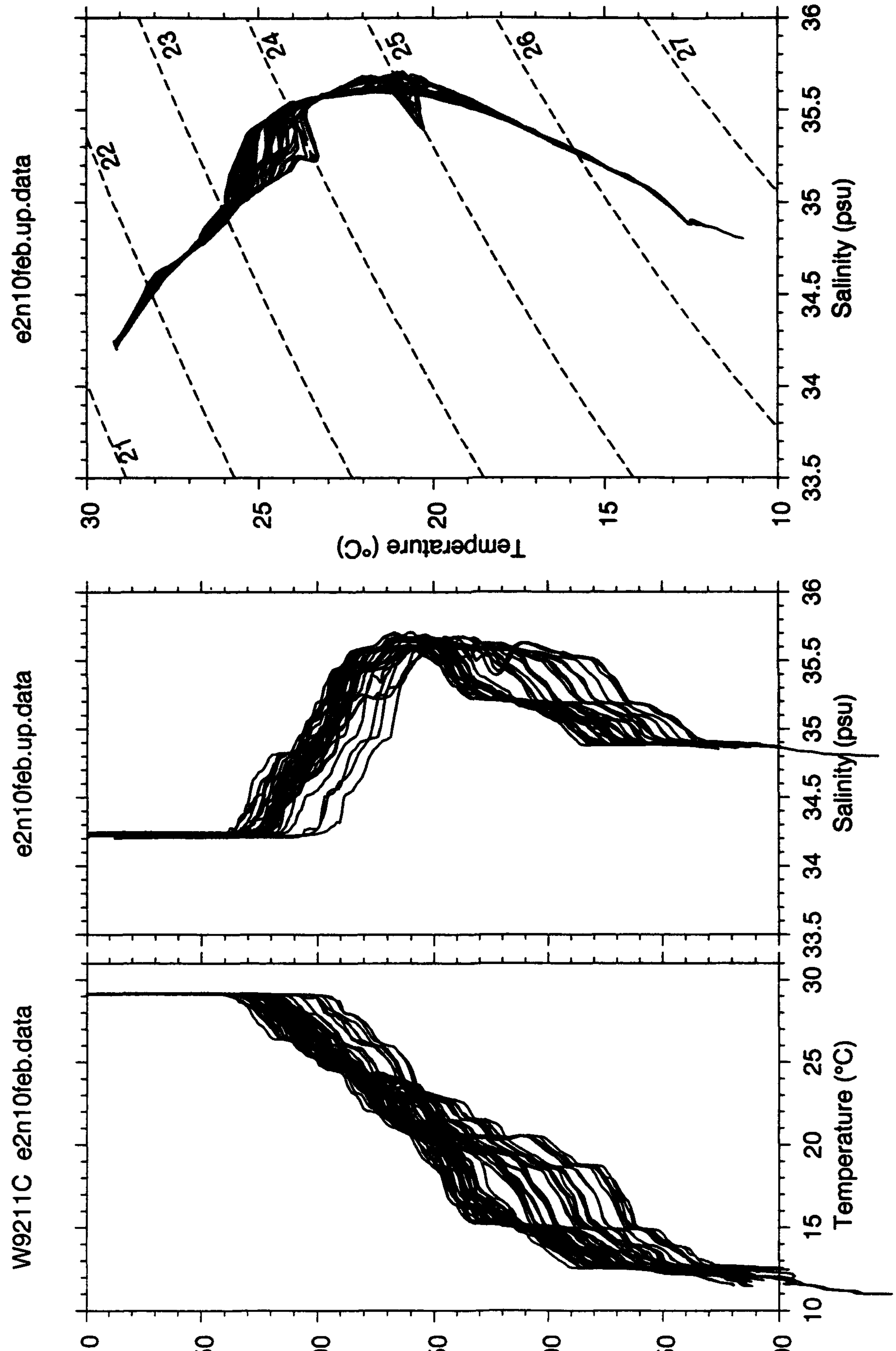
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Salinity (psu)
Salinity (psu)
Temperature (°C)
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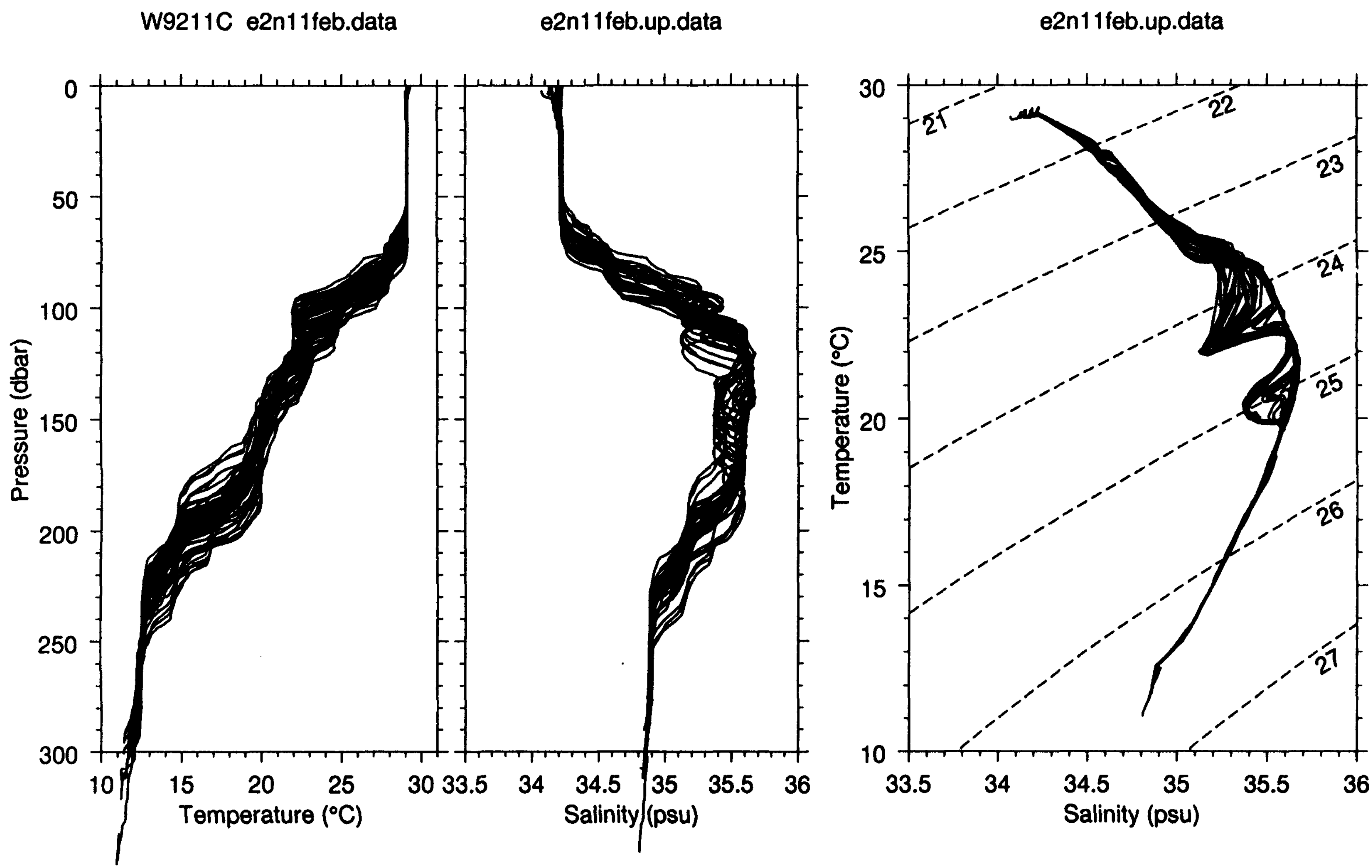
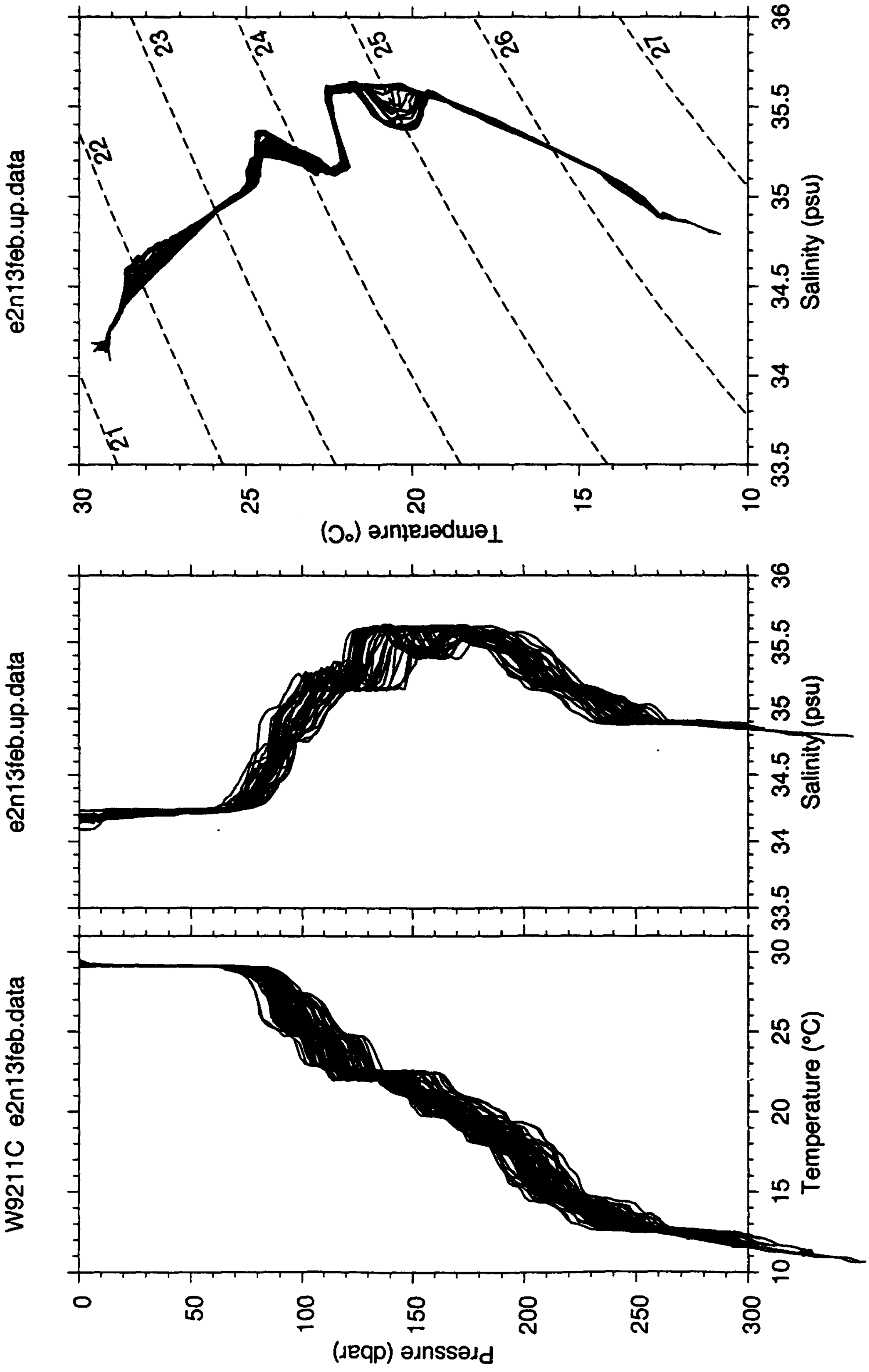
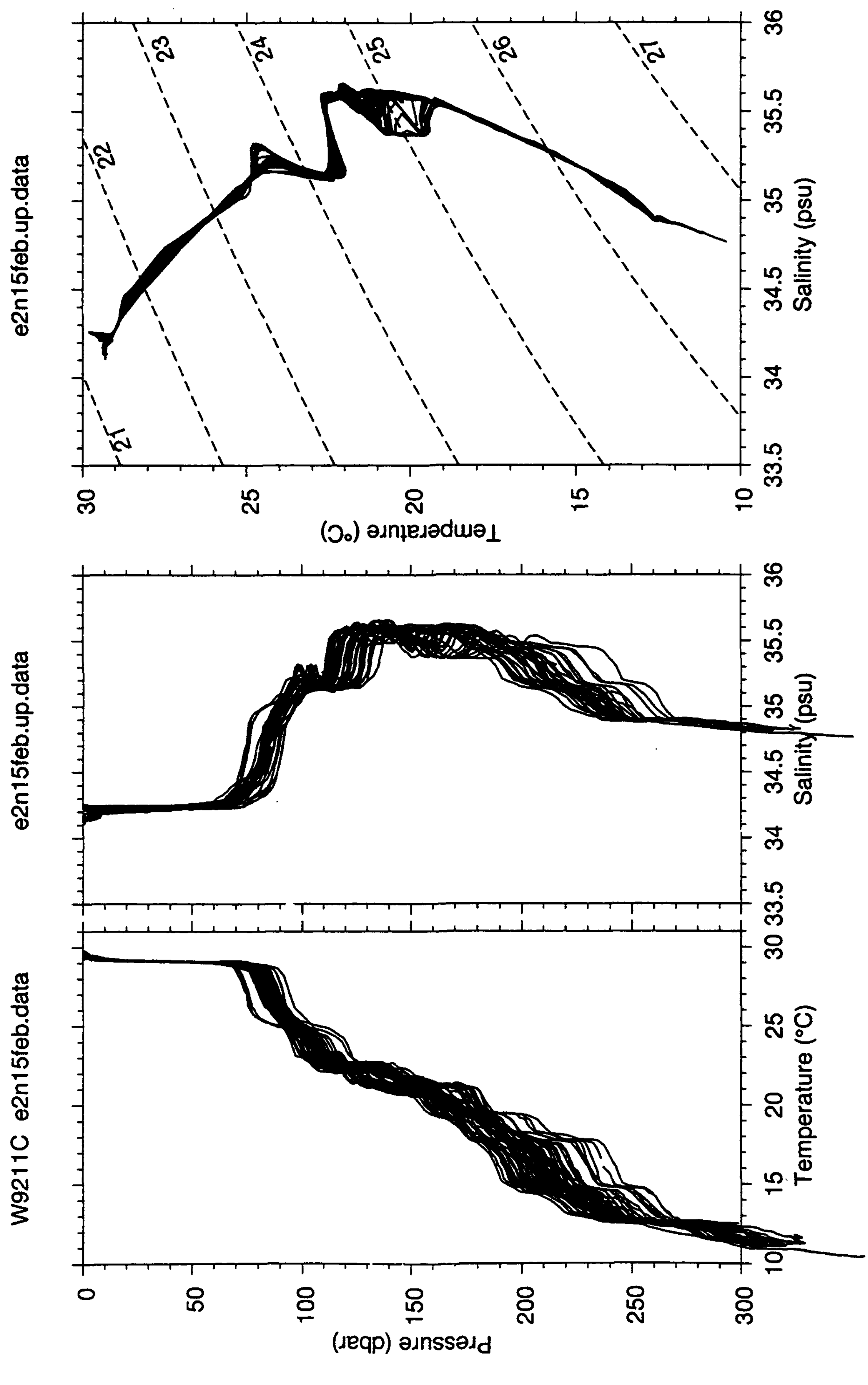
27



W9211C e2n11feb.data
e2n11feb.up.data
e2n11feb.up.data
Pressure (dbar)
0
50
100
150
200
250
300
10
15
20
25
30
Temperature (°C)
33.5
34
34.5
35
35.5
36
Salinity (psu)
33.5
34
34.5
35
35.5
36
Salinity (psu)
Temperature (°C)
30
25
20
15
10
21
22
23
24
25
26
27


W9211C e2n13feb.data
Pressure (dbar)
Temperature (°C)
e2n13feb.up.data
Salinity (psu)
e2n13feb.up.data
Temperature (°C)
Salinity (psu)
21
22
23
24
25
26
27


W9211C e2n15feb.data
e2n15feb.up.data
e2n15feb.up.data
Pressure (dbar)
Temperature (°C)
Salinity (psu)
Salinity (psu)
Temperature (°C)
0
50
100
150
200
250
300
10
15
20
25
30
33.5
34
34.5
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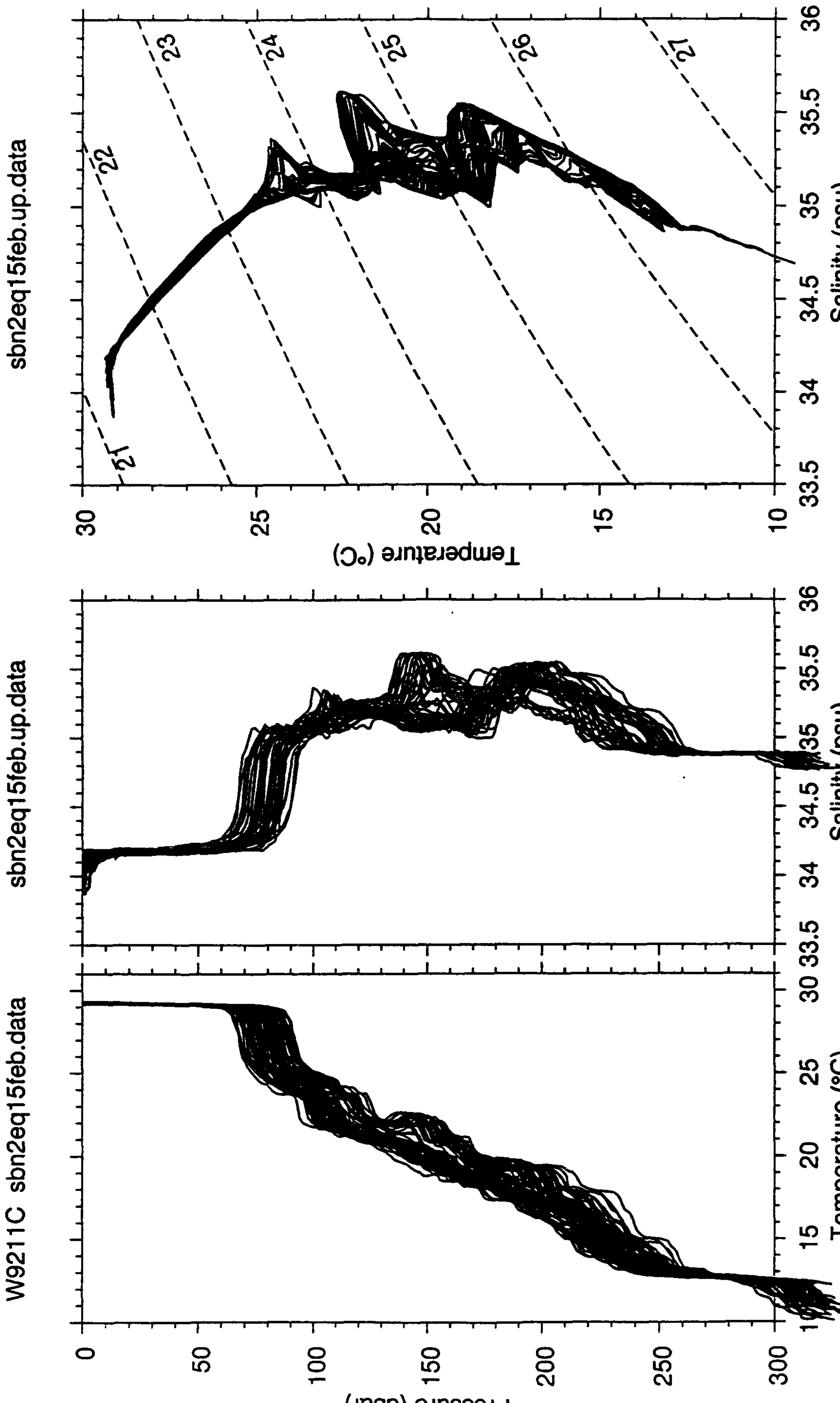
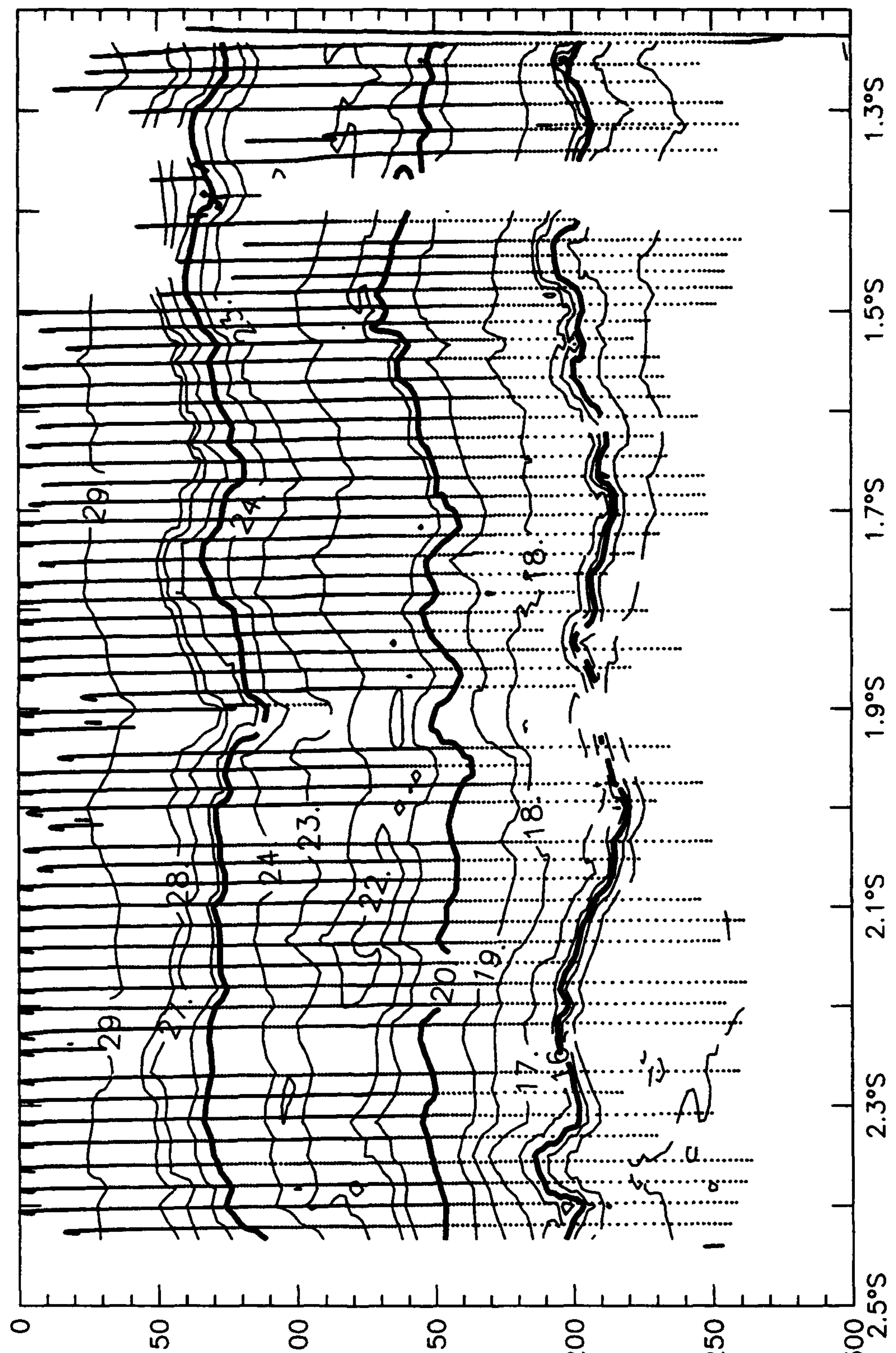
23
24
25
26
27


W9211C sbn2eq15feb.data
sbn2eq15feb.up.data
sbn2eq15feb.up.data
Pressure (dbar)
Temperature (°C)
Salinity (psu)
Temperature (°C)
Salinity (psu)
21
22
23
24
25
26
27

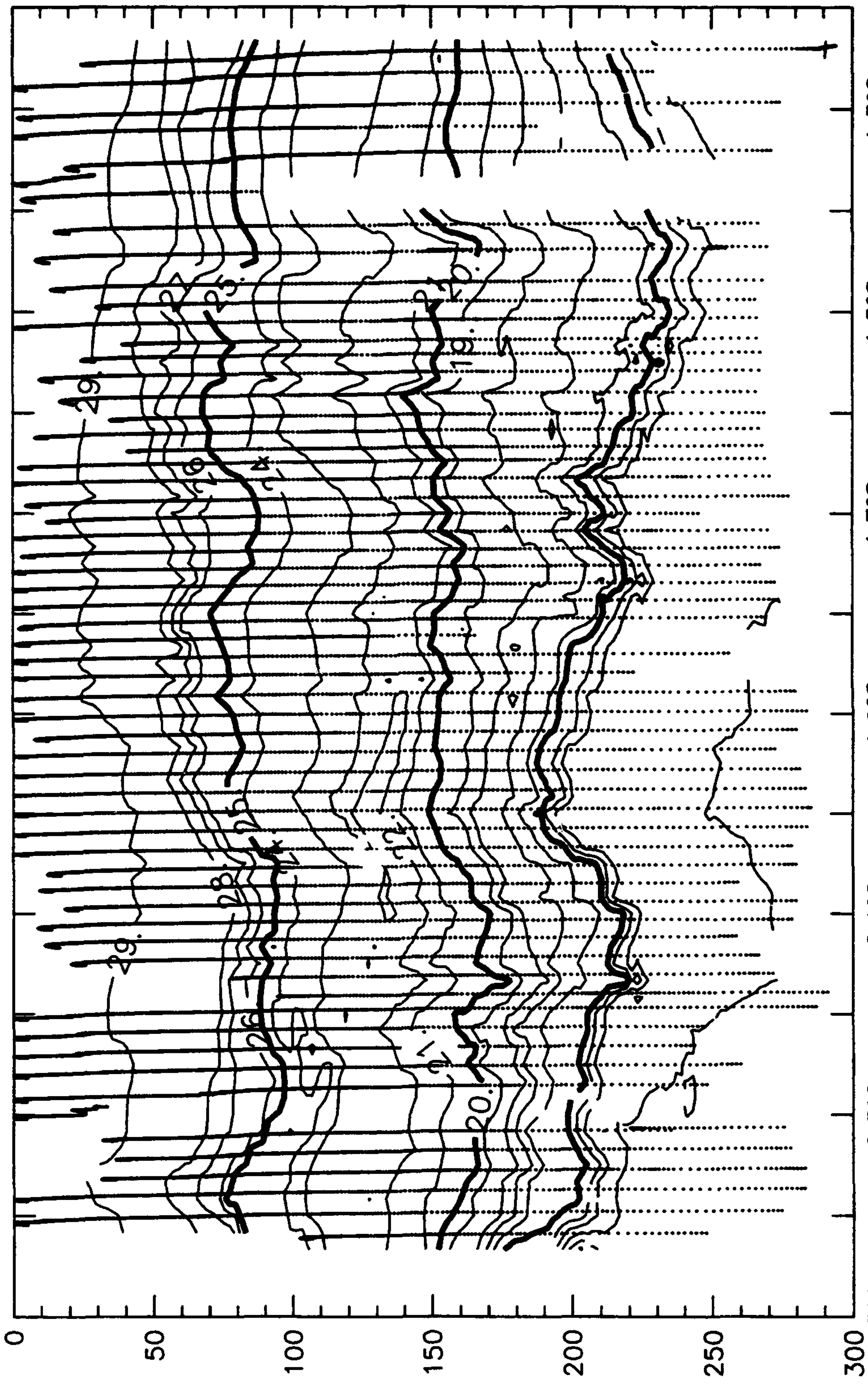
VERTICAL SECTIONS

OF

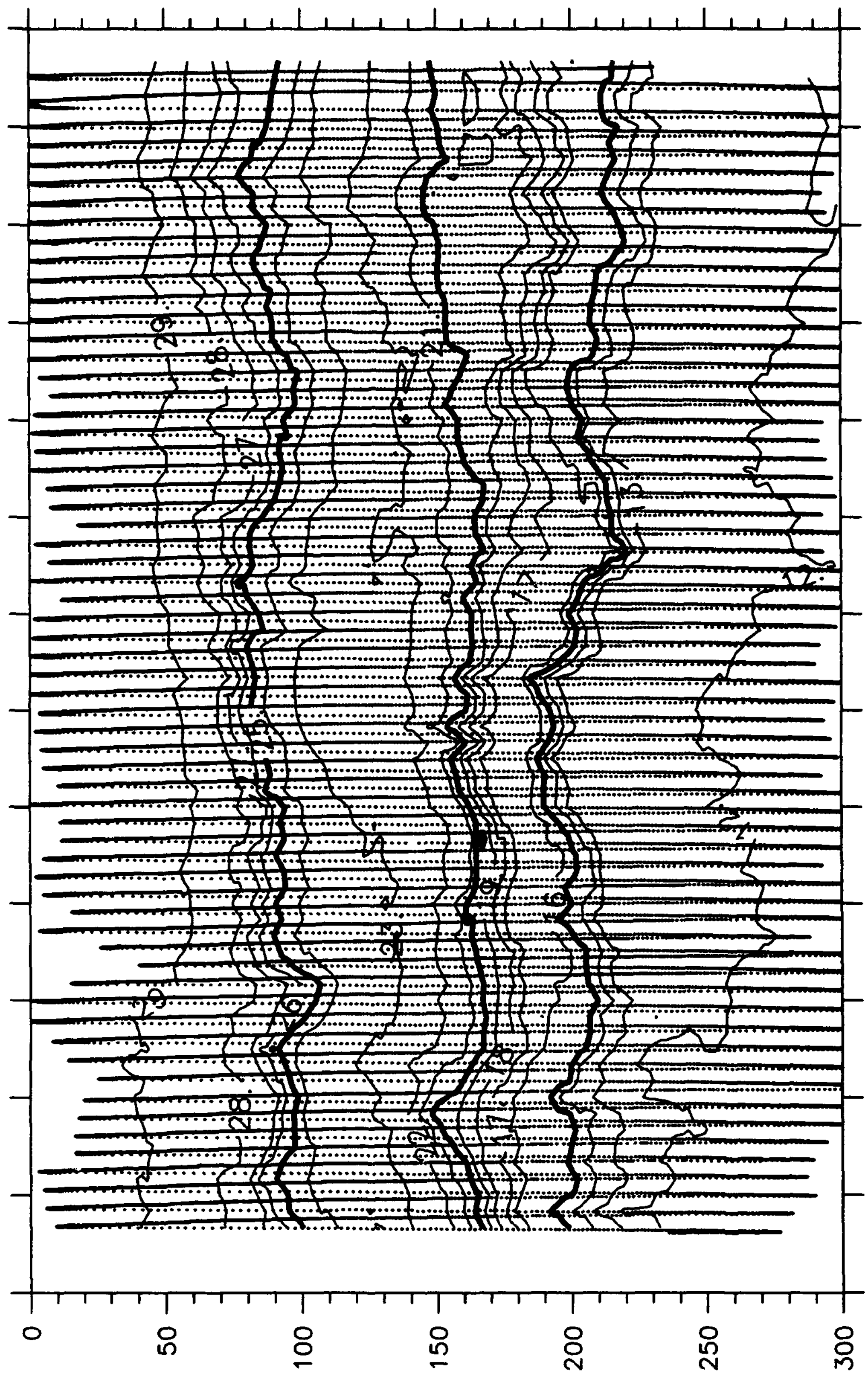
TEMPERATURE, SALINITY AND SIGMA-T



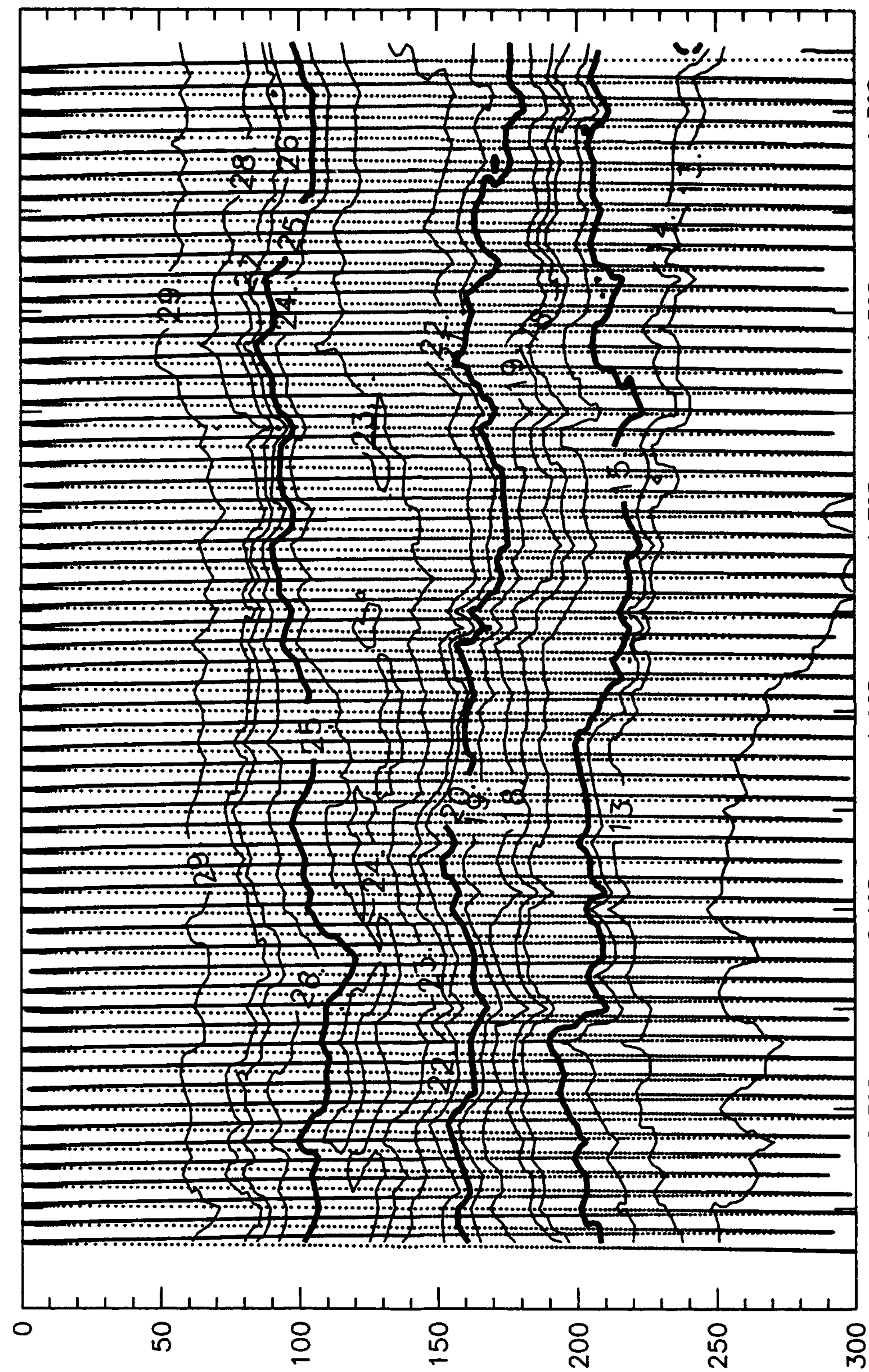
T(°C), N2S, 27 January 1993



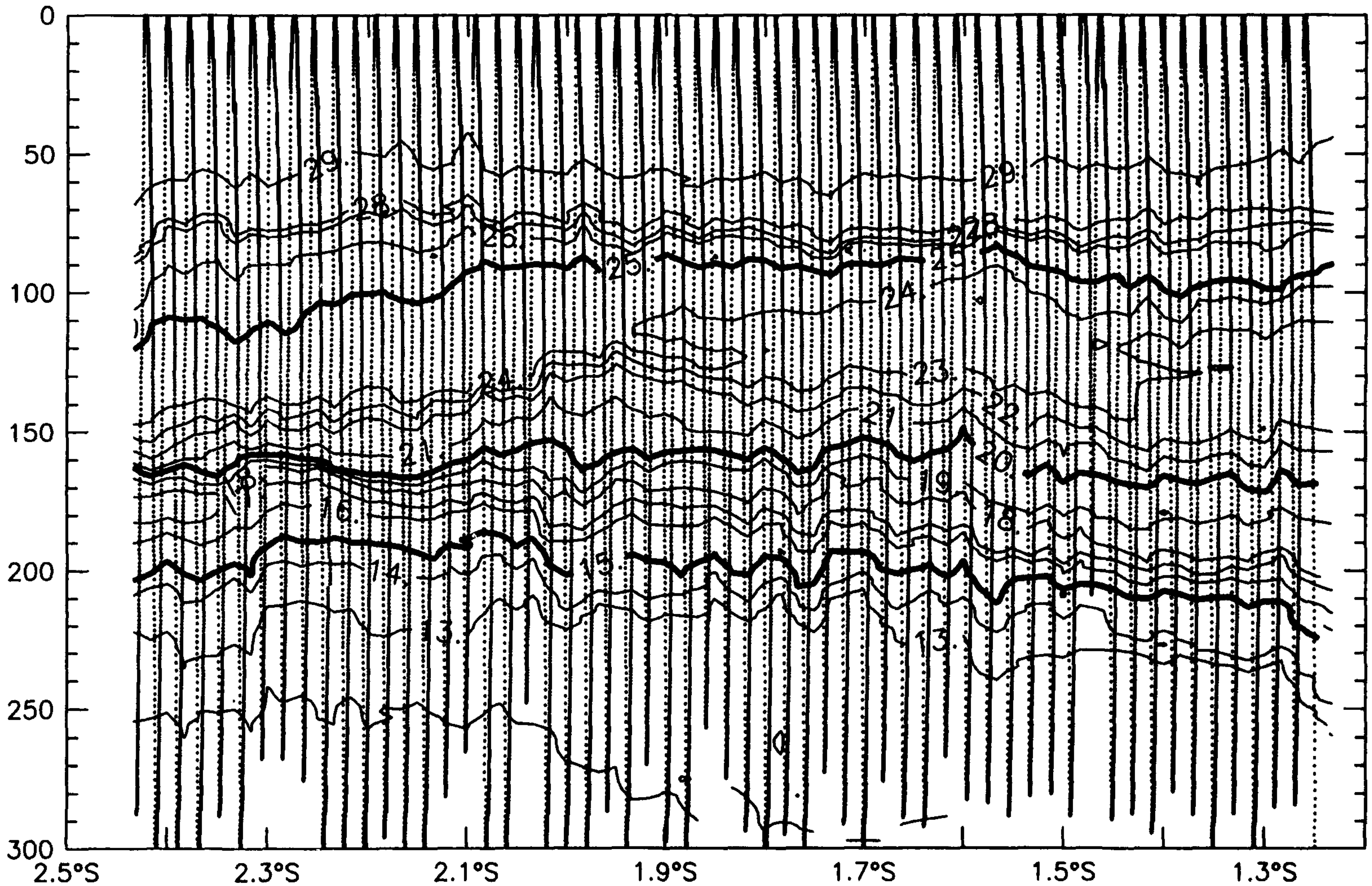
T(°C), N2S, 28 January 1993



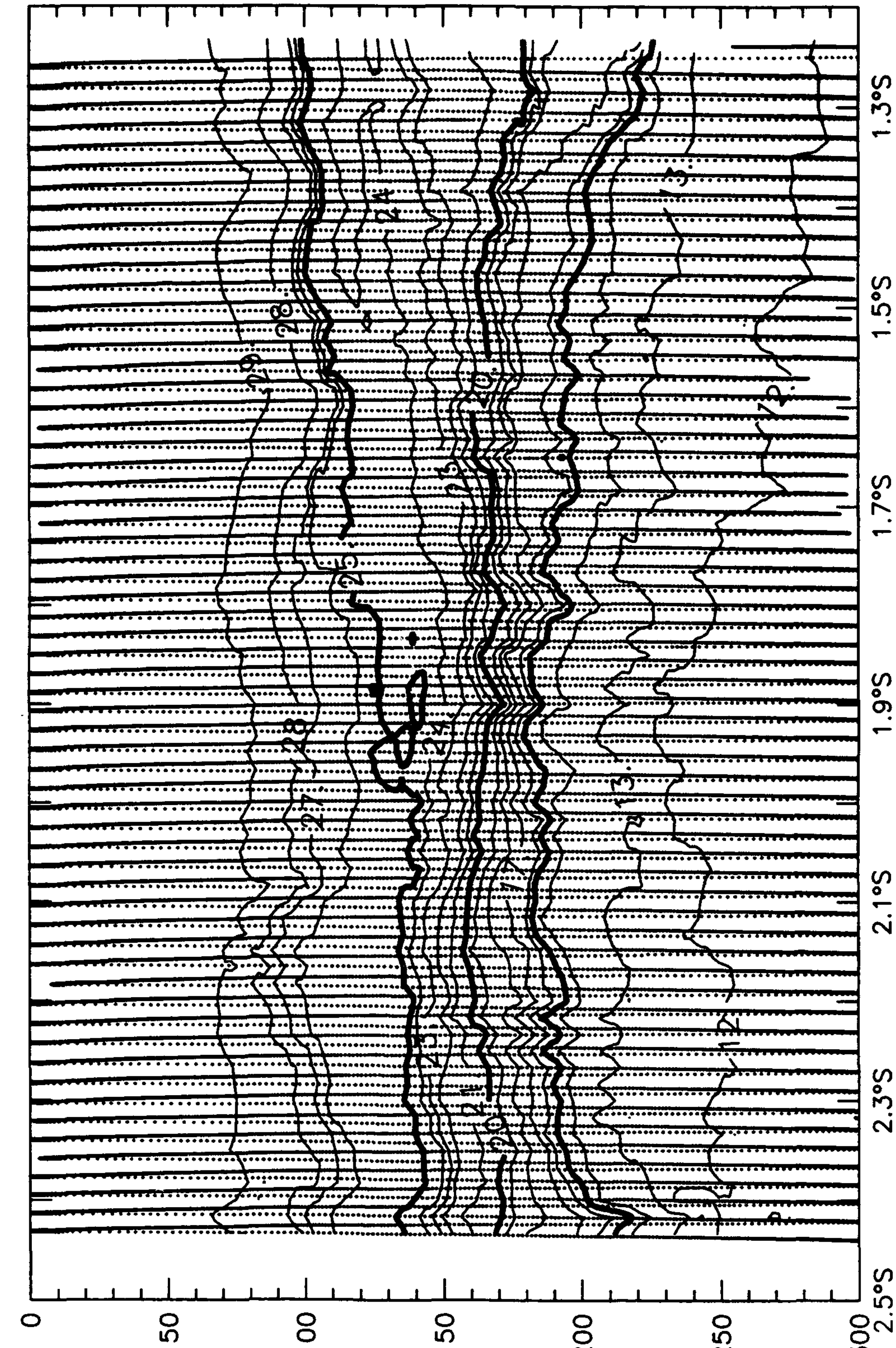
T(°C), N2S, 30 January 1993



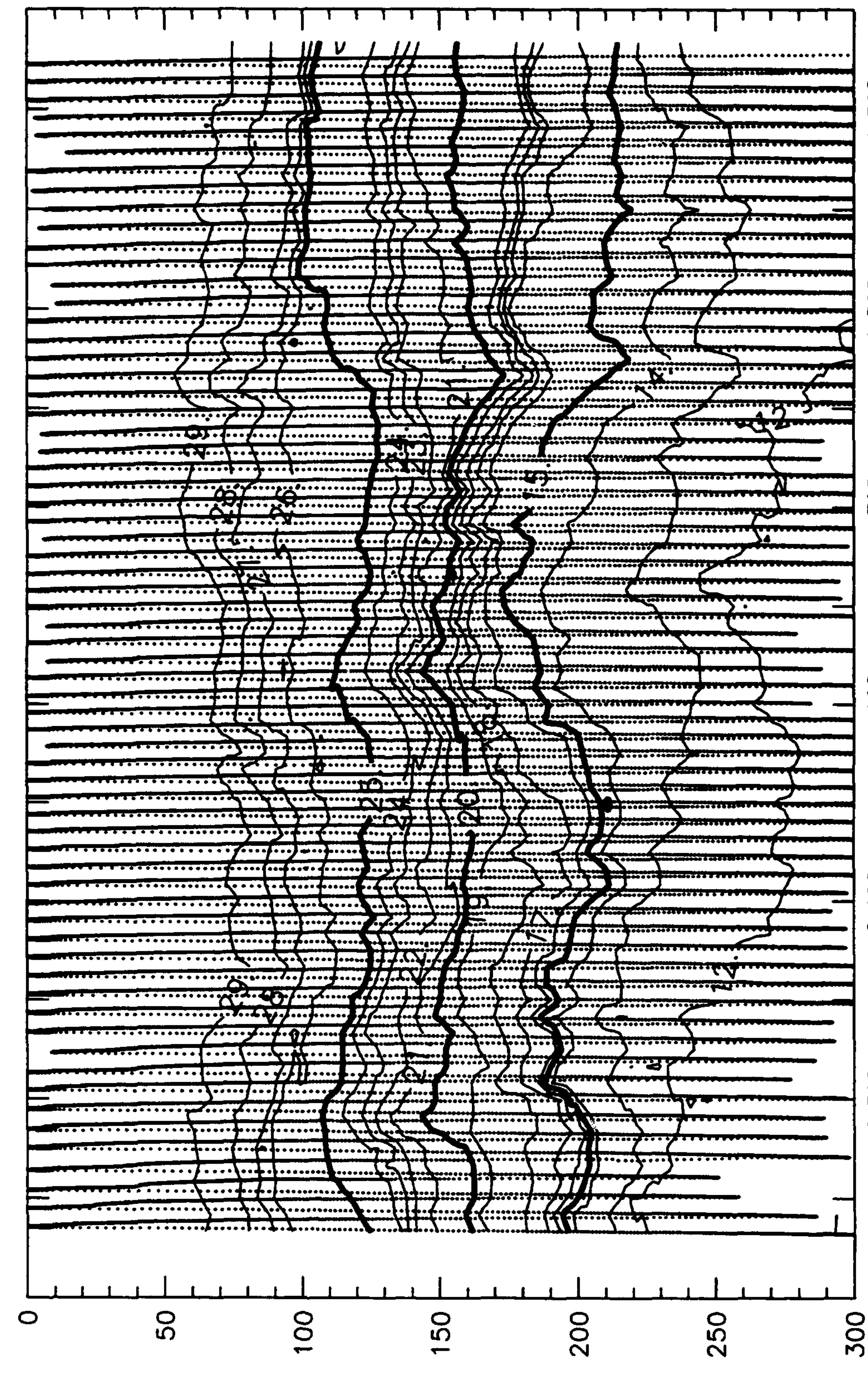
T(°C), N2S, 31 January 1993



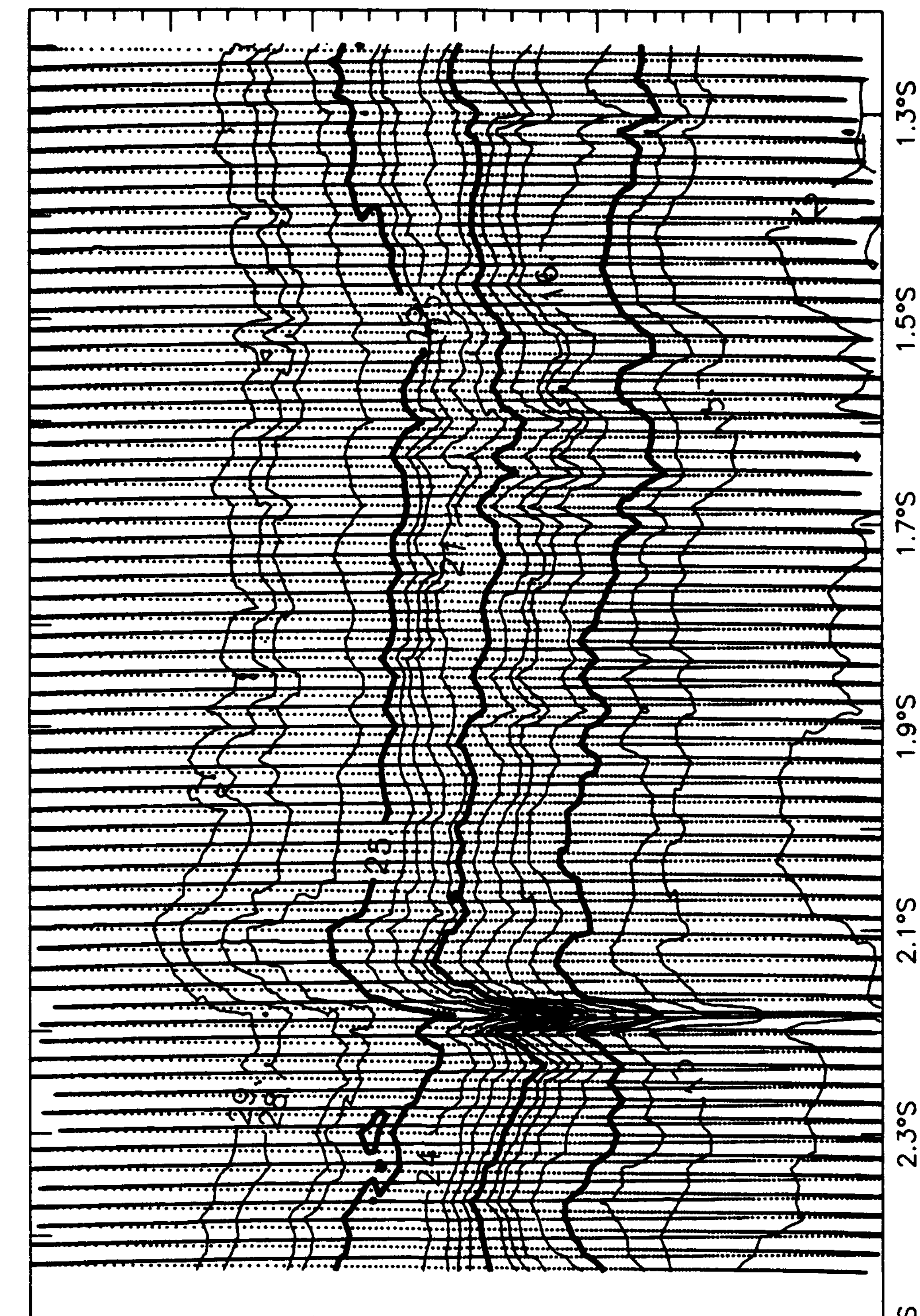
T(°C), N2S, 2 February 1993



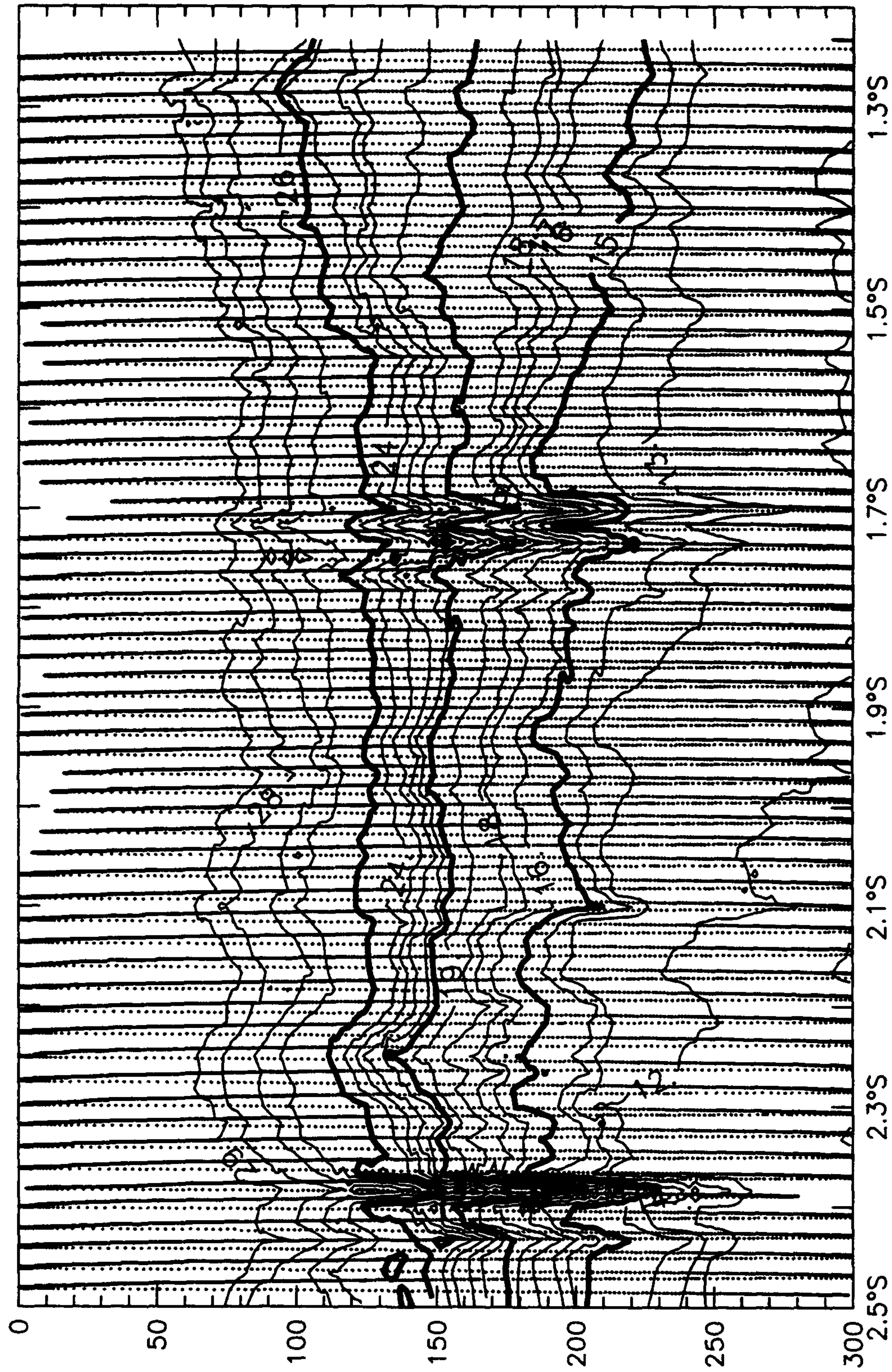
T(°C), N2S, 4 February 1993



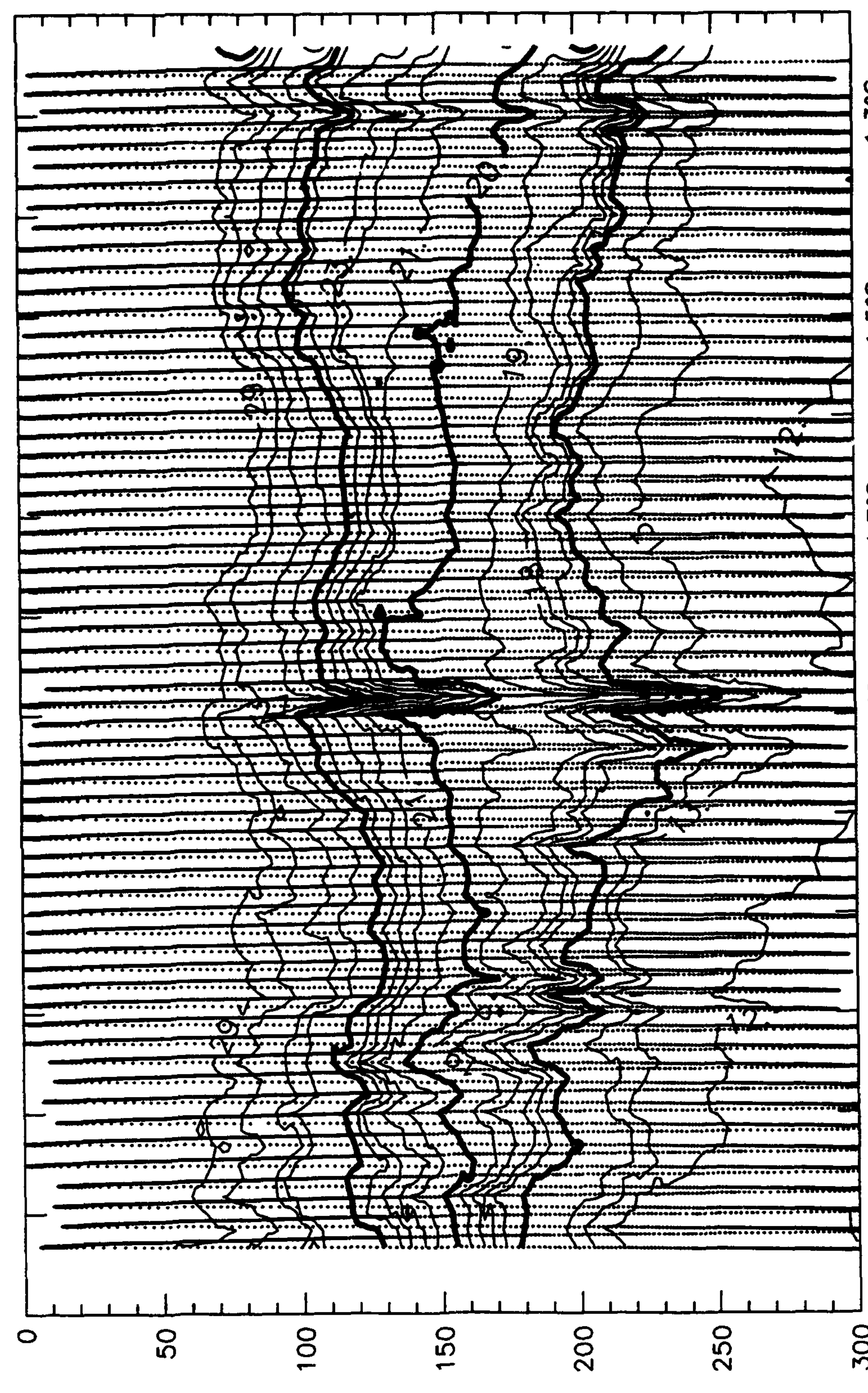
T(°C), N2S, 5 February 1993



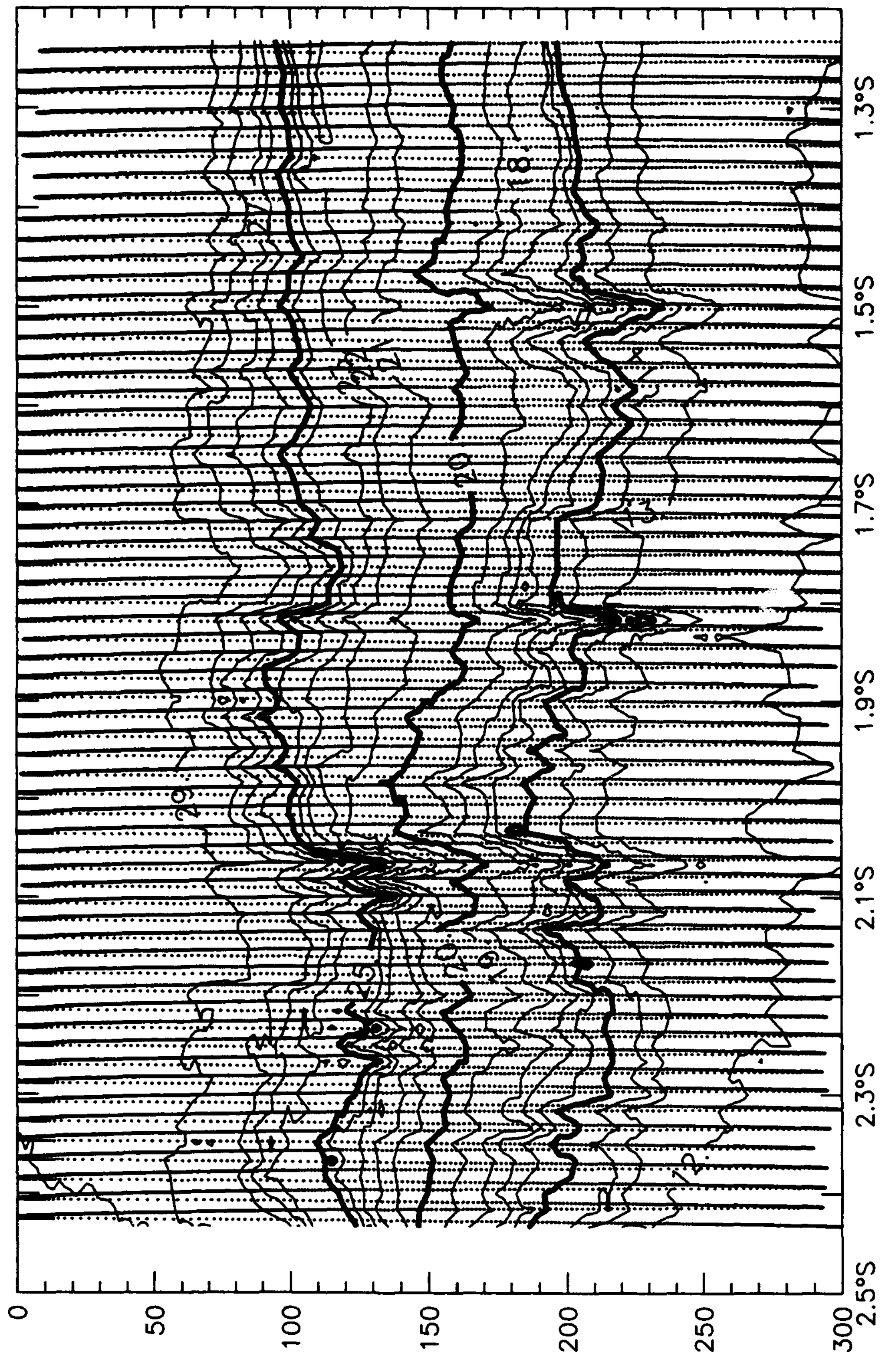
T(°C), N2S, 7 February 1993



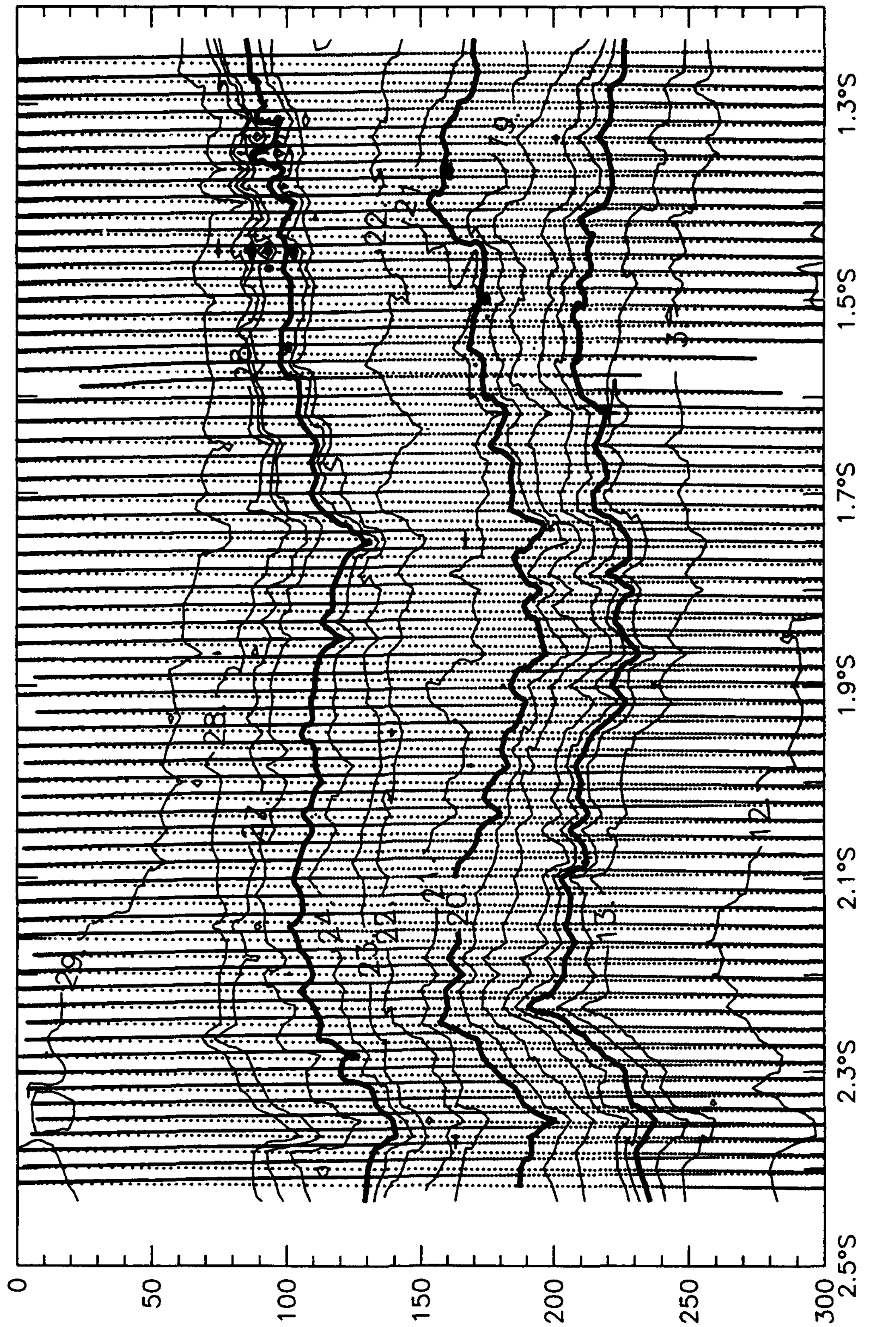
T(°C), N2S, 9 February 1993



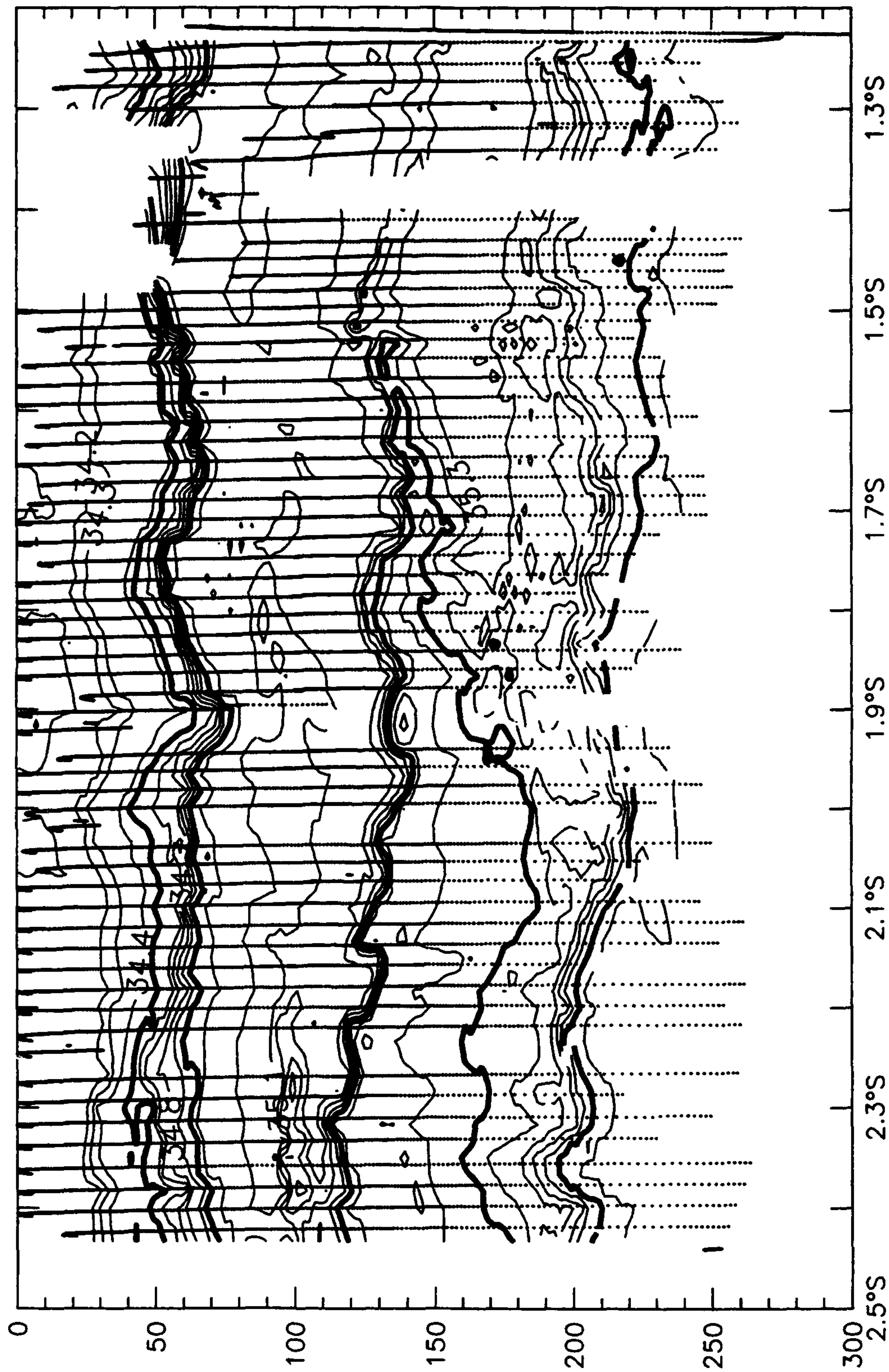
T(°C), N2S, 10 February 1993



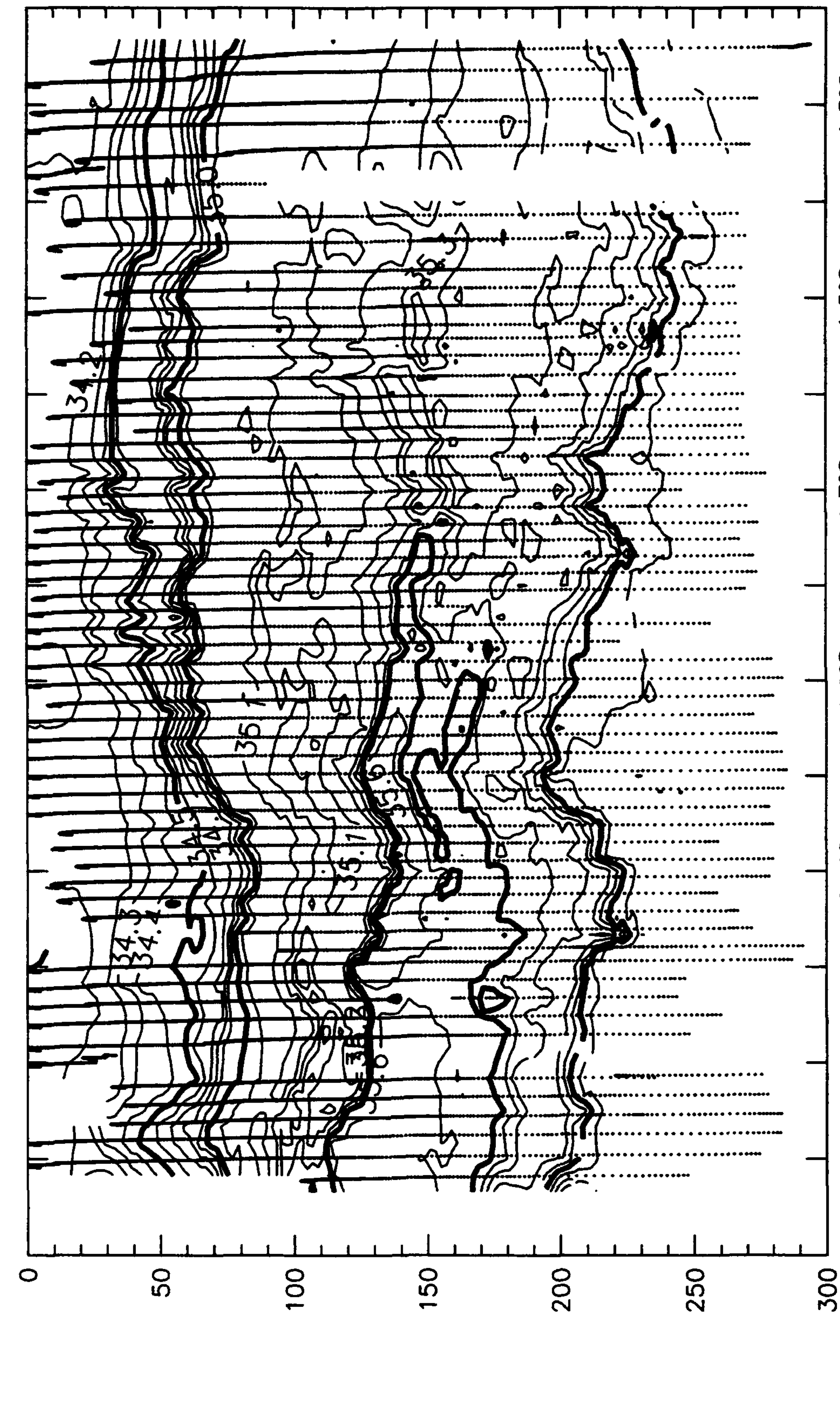
T(°C), N2S, 12 February 1993



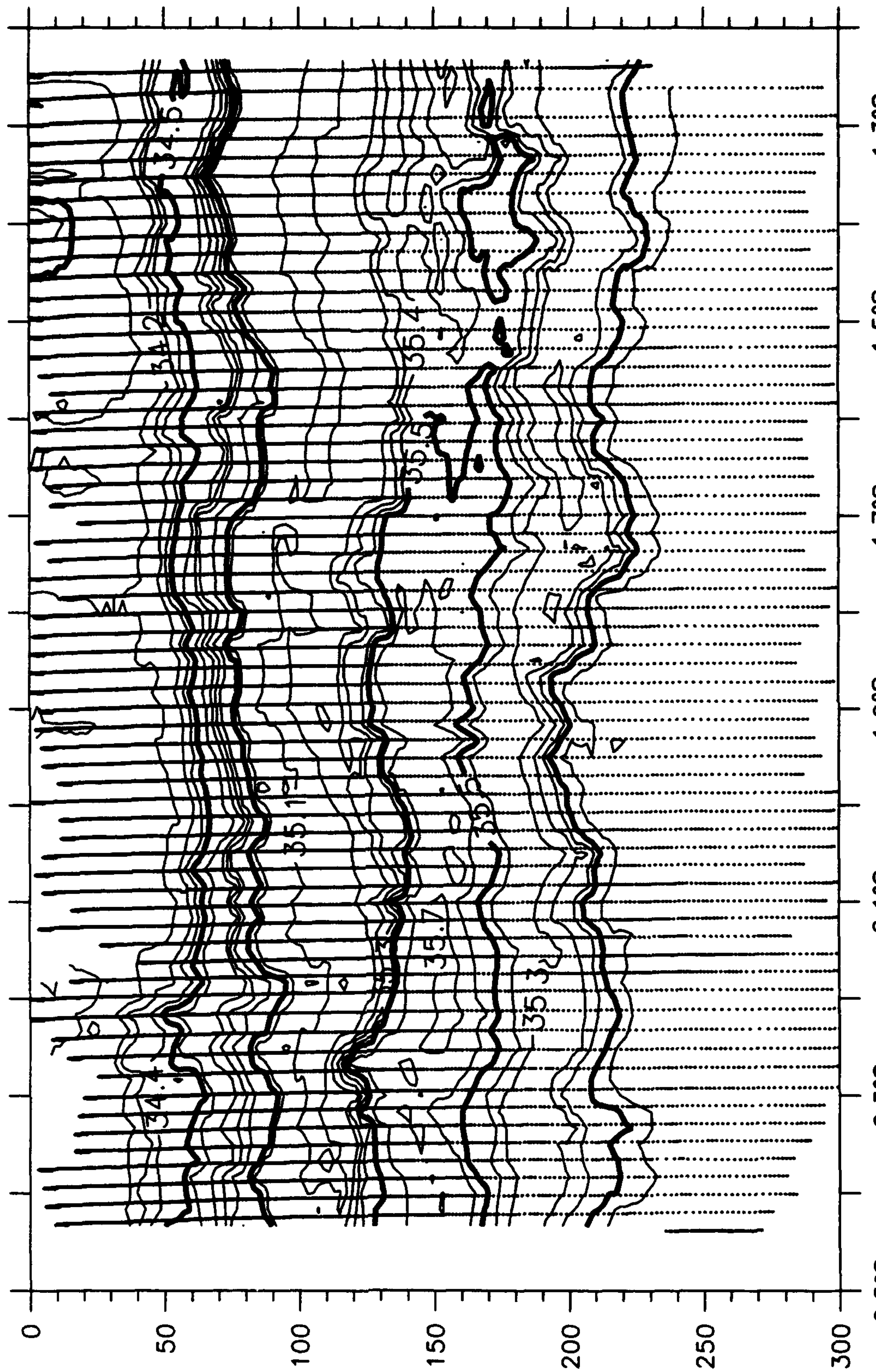
T(°C), N2S, 14 February 1993



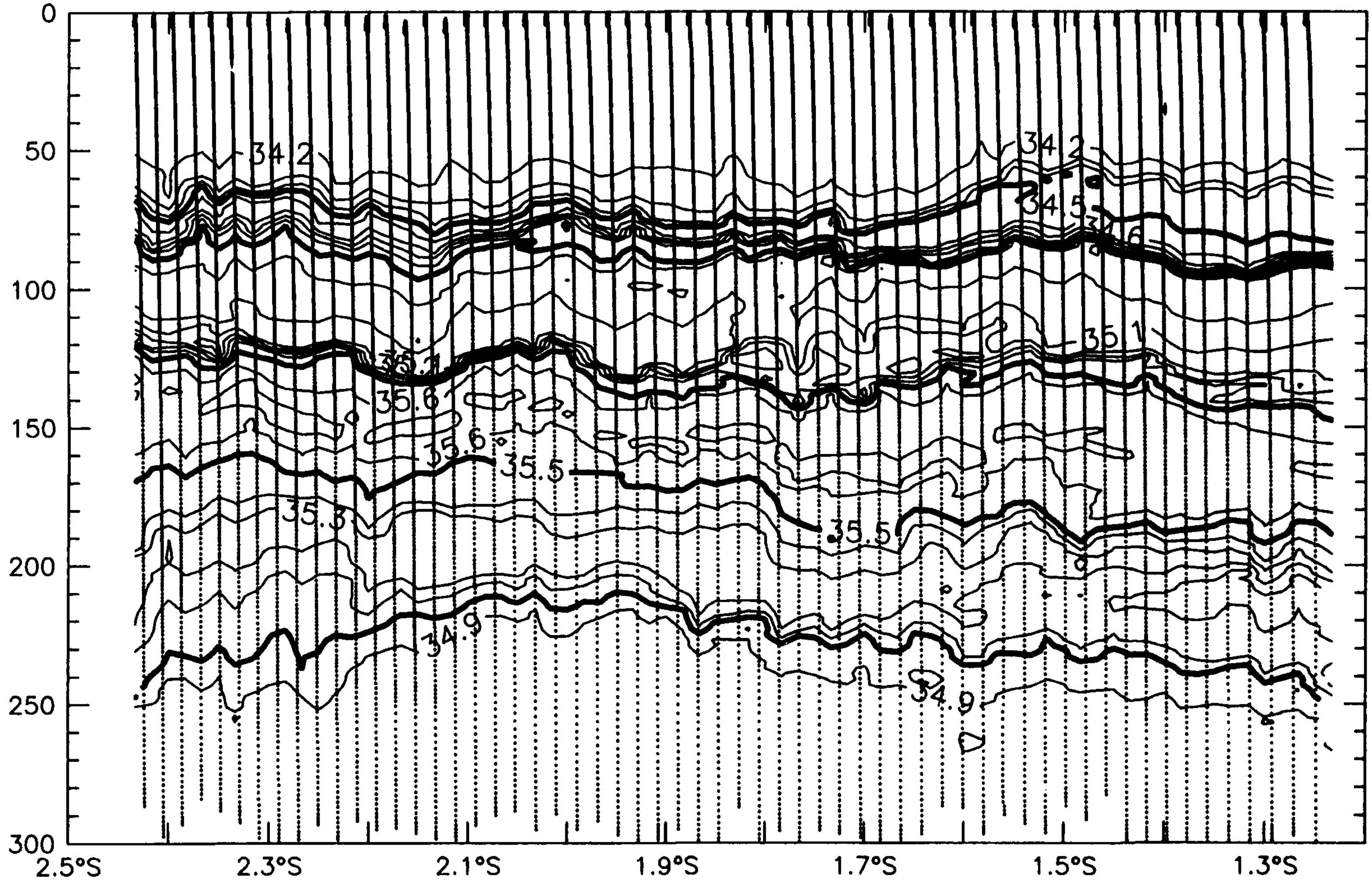
S(psu), N2S, 27 January 1993



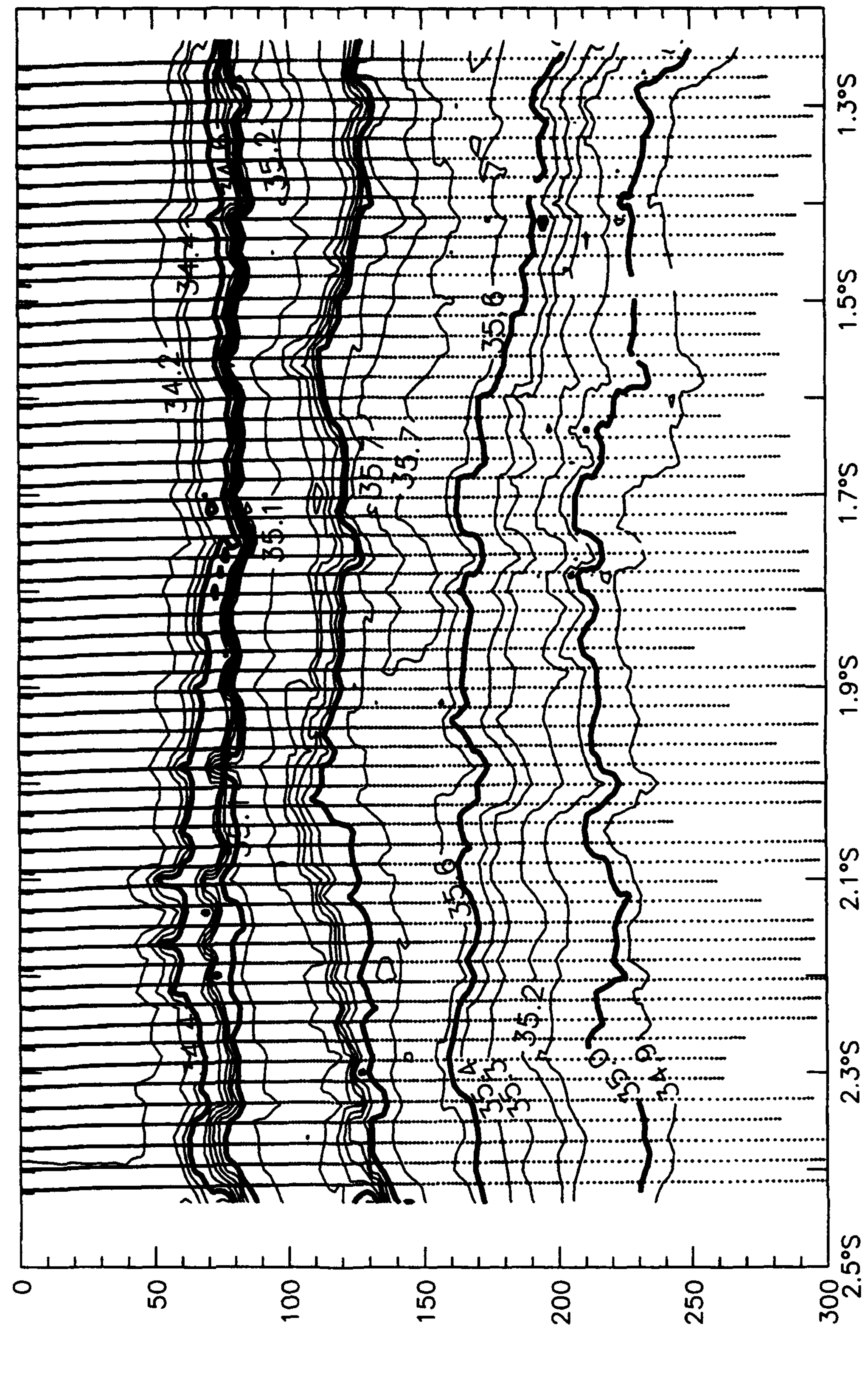
S(psu), N2S, 28 January 1993



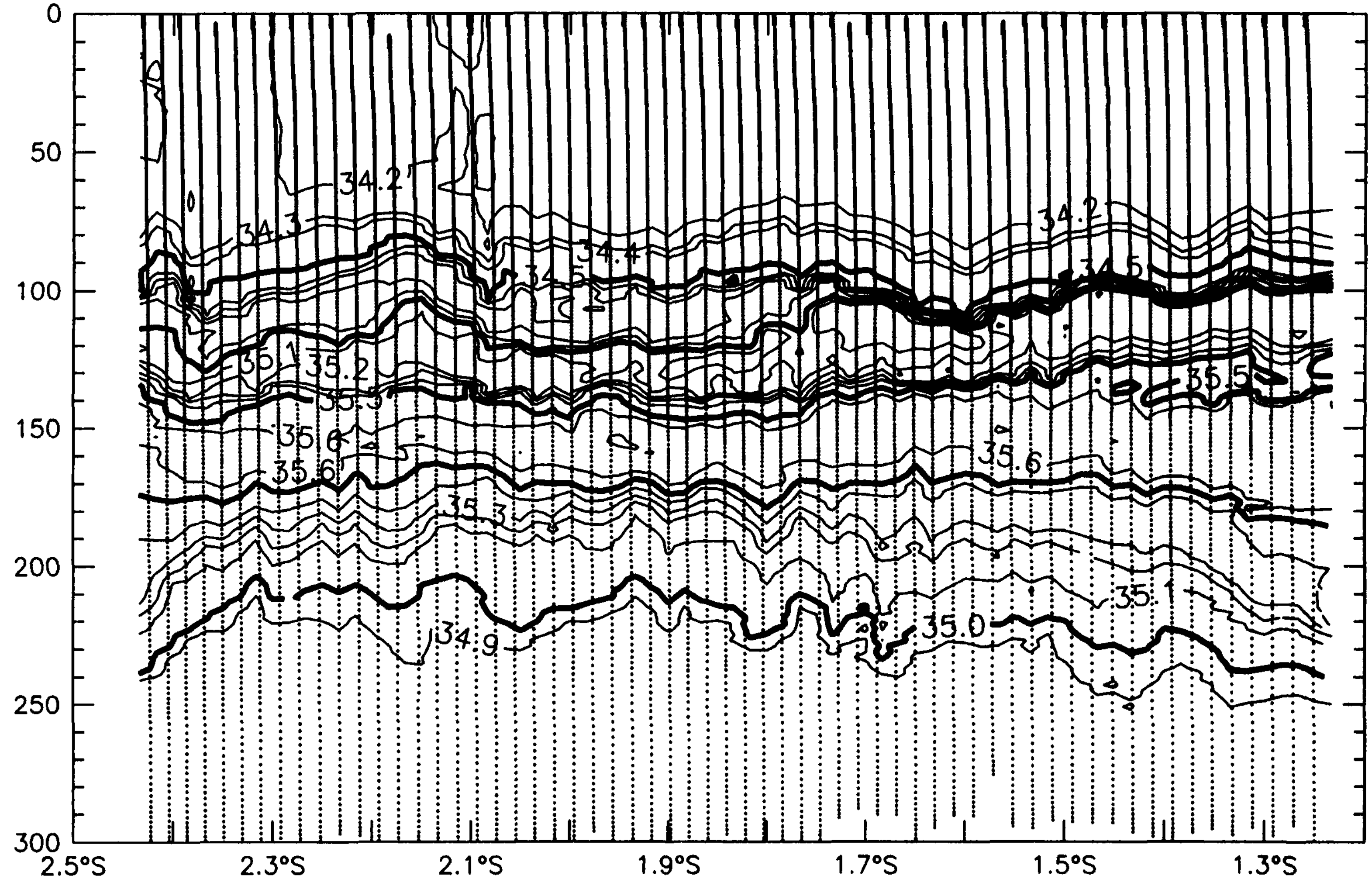
S(psu), N2S, 30 January 1993



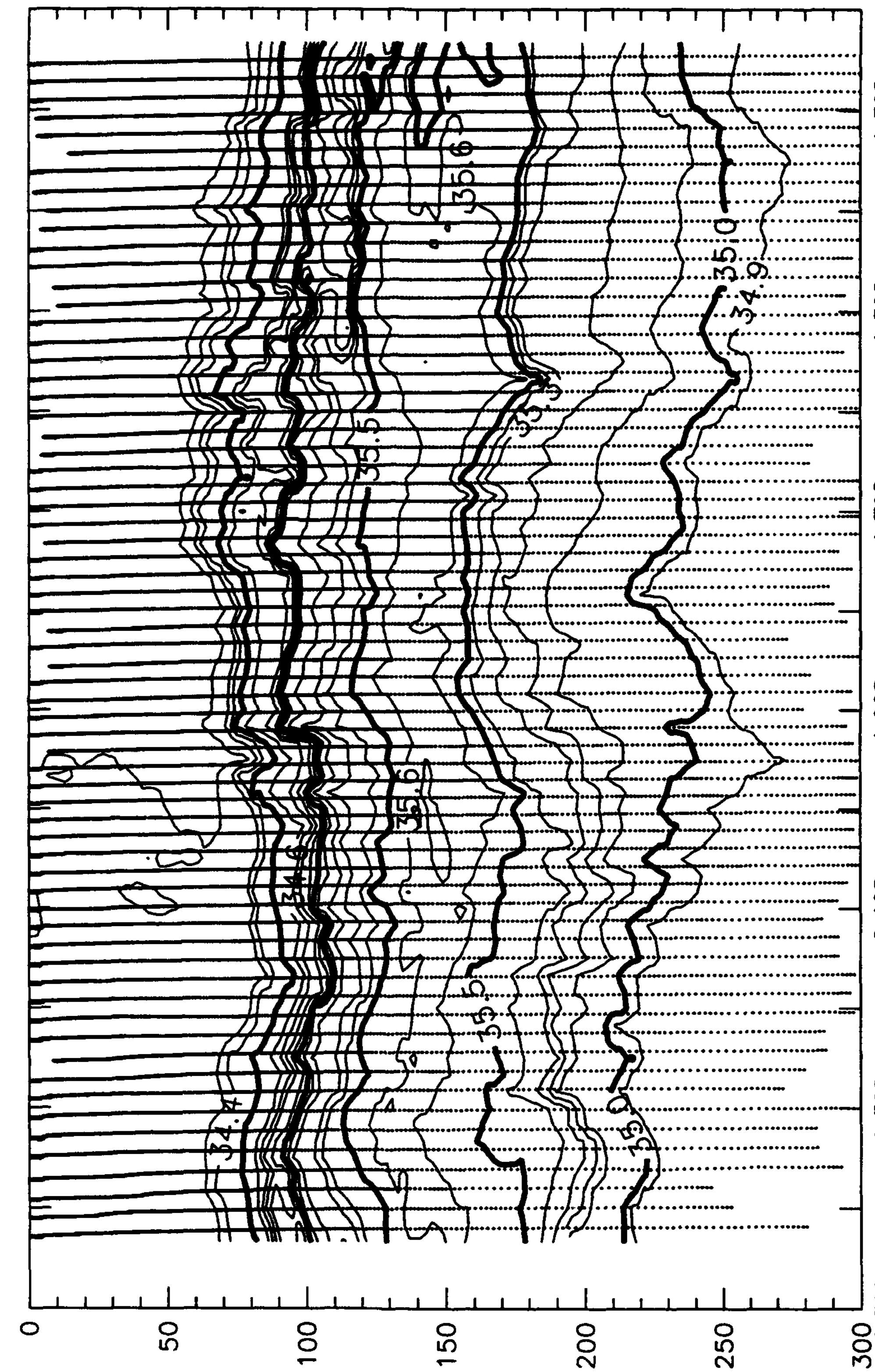
S(psu), N2S, 31 January 1993



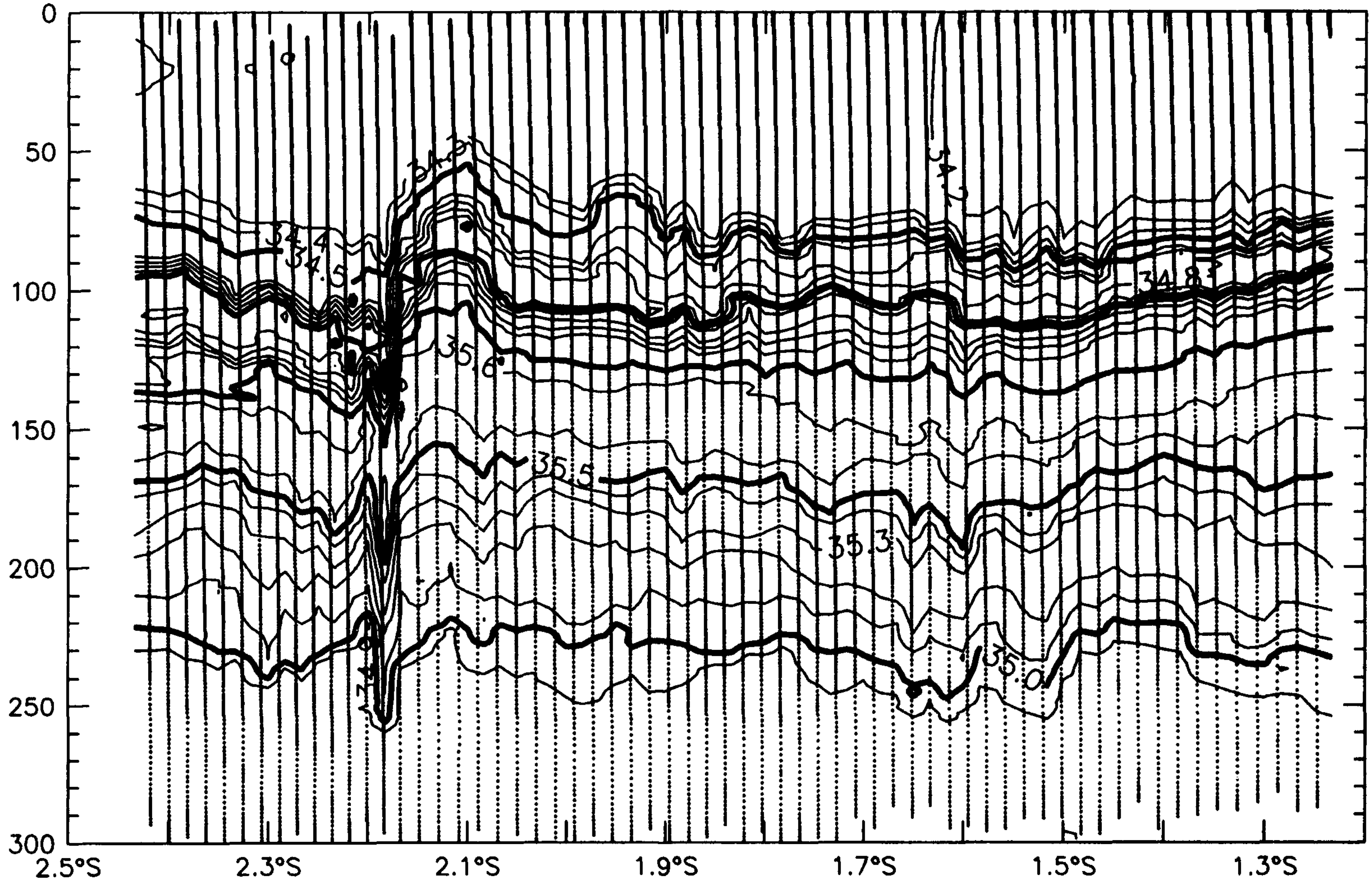
S(psu), N2S, 2 February 1993



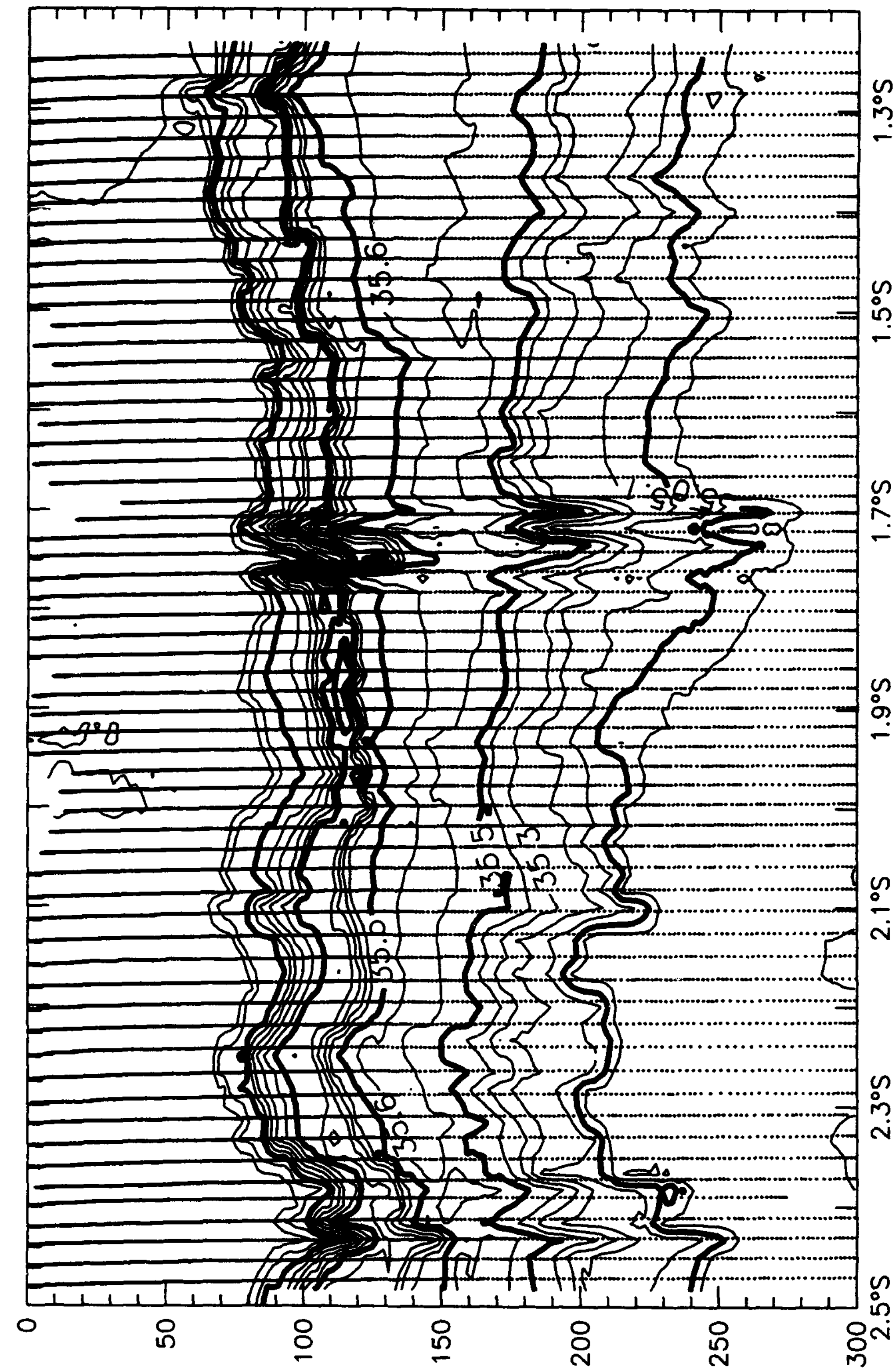
S(psu), N2S, 4 February 1993



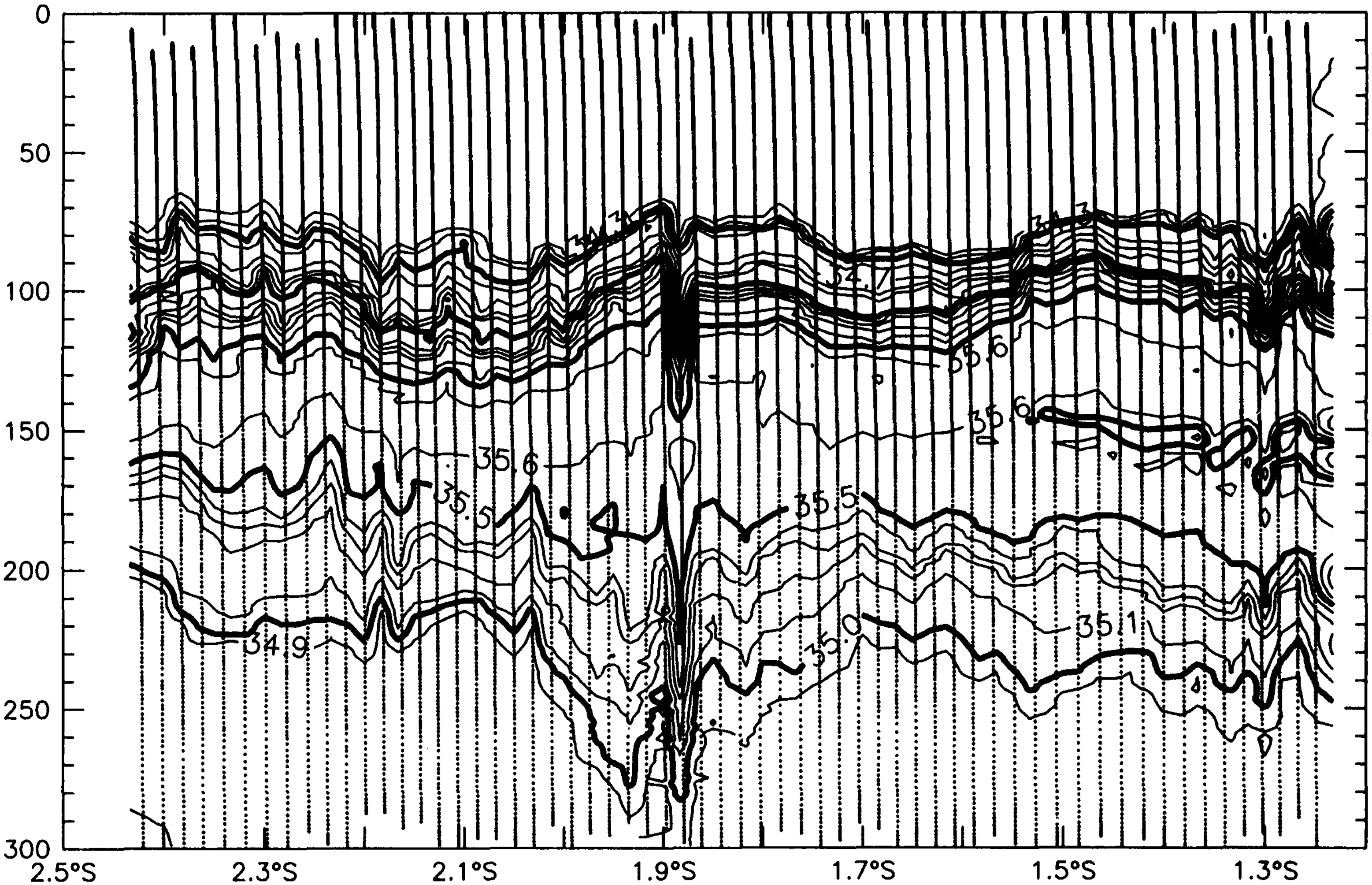
S(psu), N2S, 5 February 1993



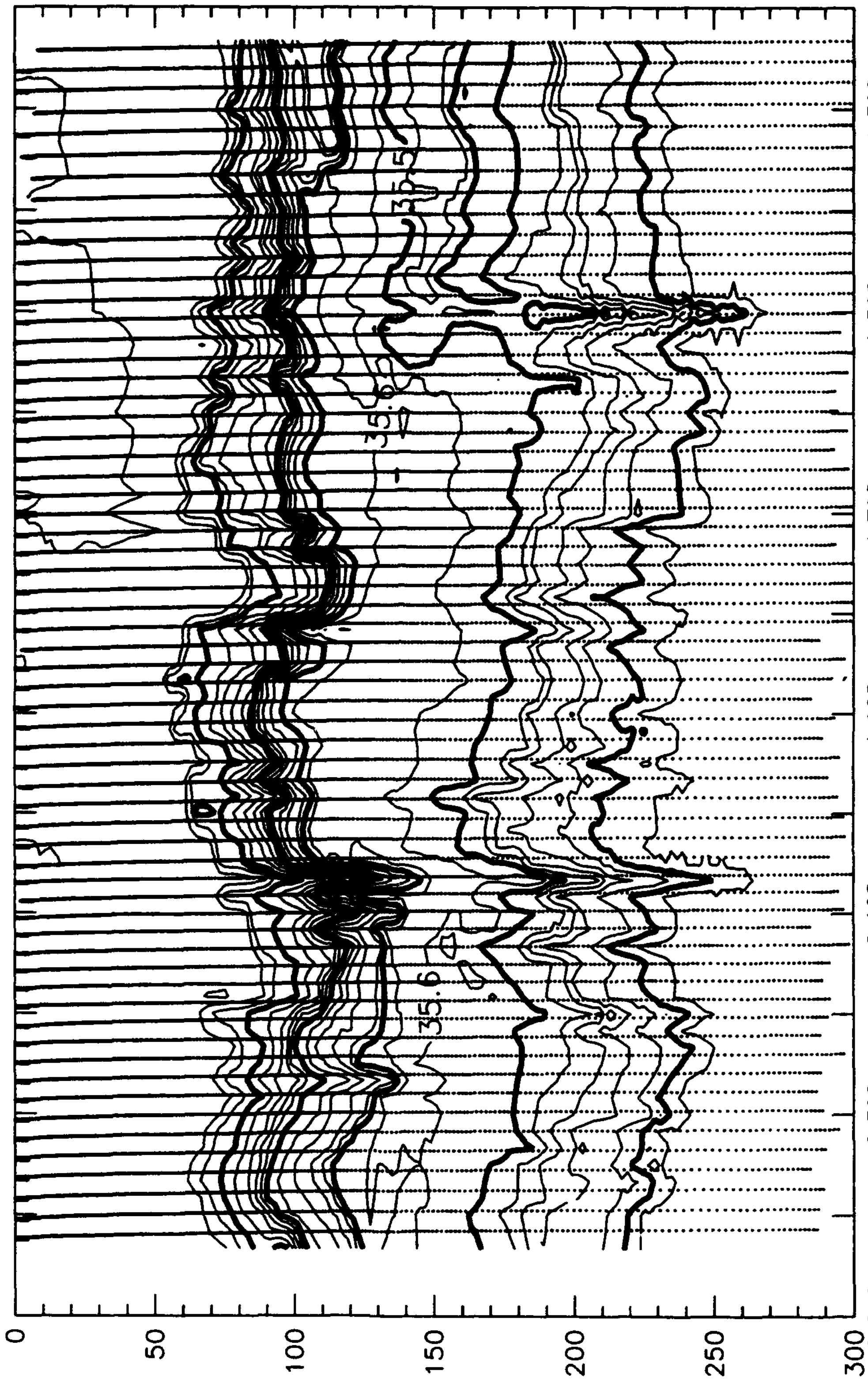
S(psu), N2S, 7 February 1993



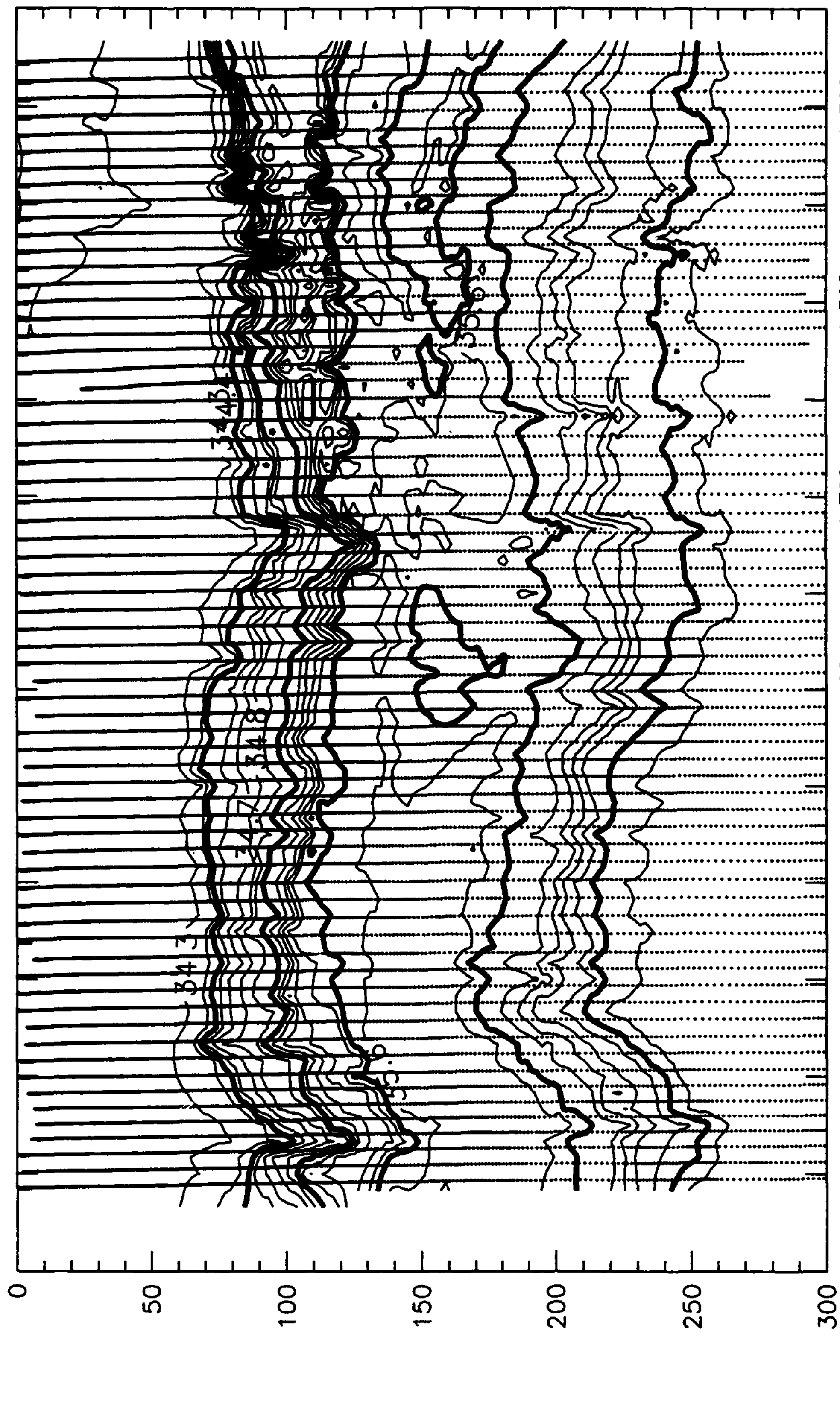
S(psu), N2S, 9 February 1993



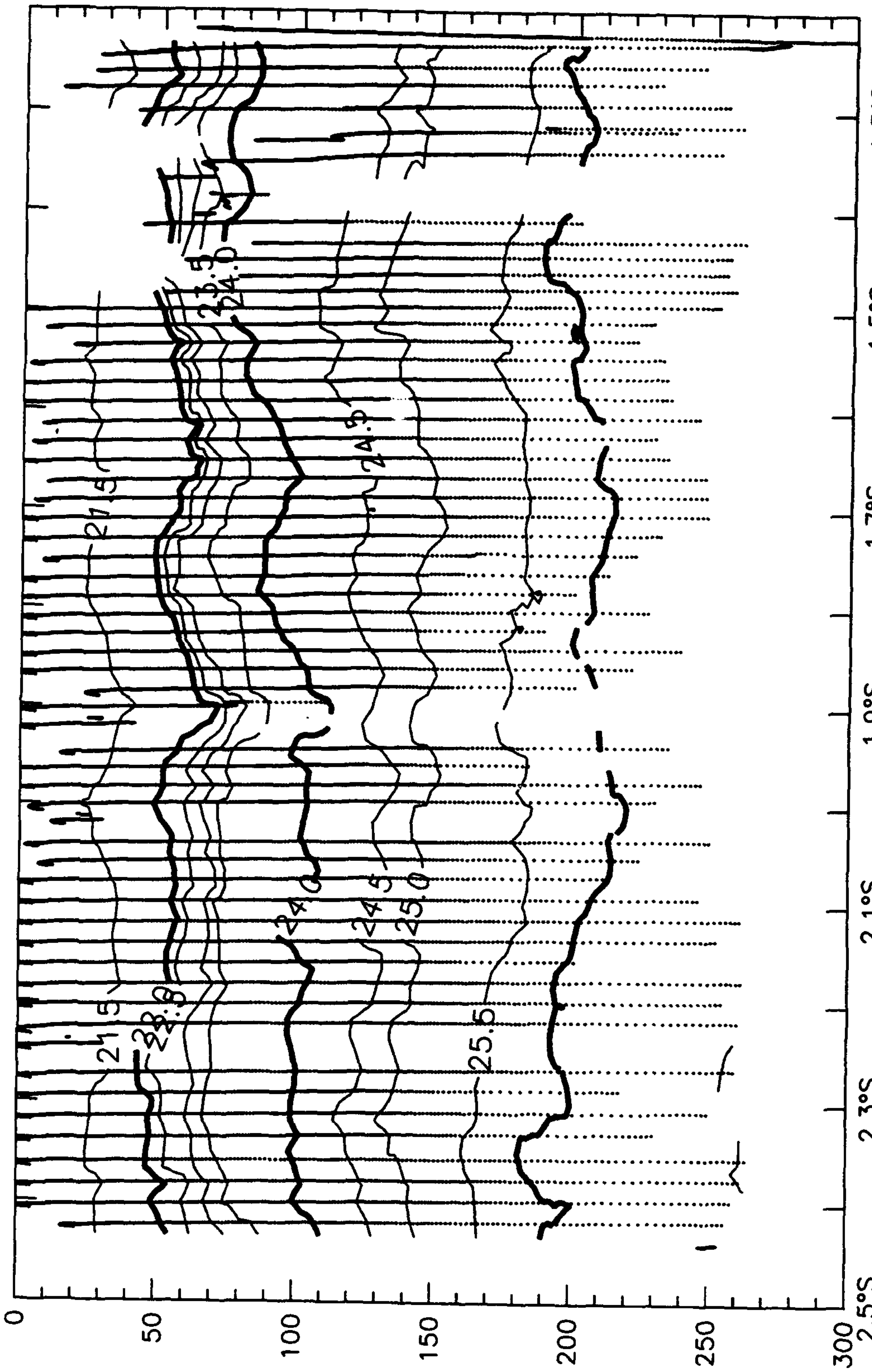
S(psu), N2S, 10 February 1993



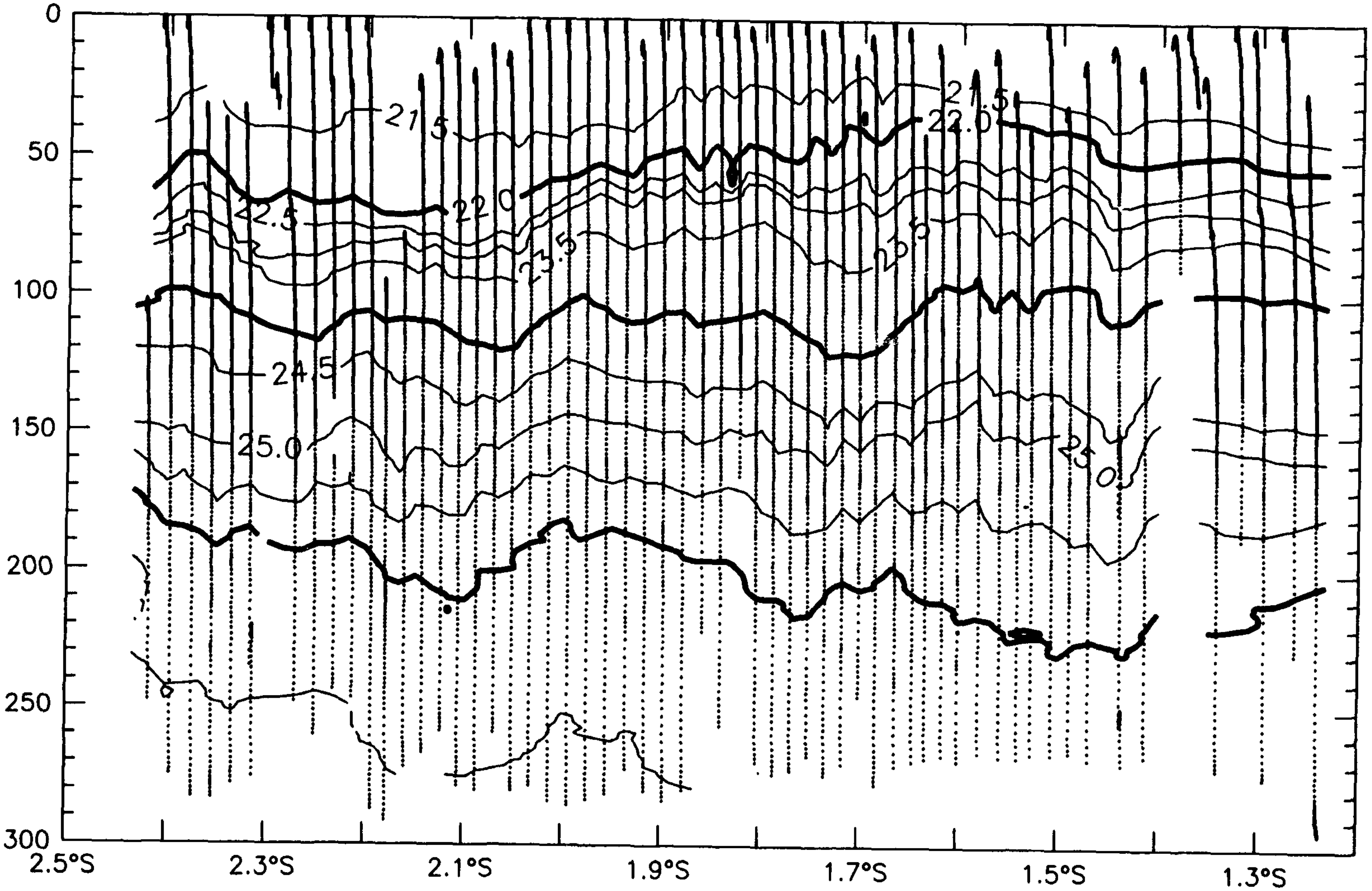
S(psu), N2S, 12 February 1993



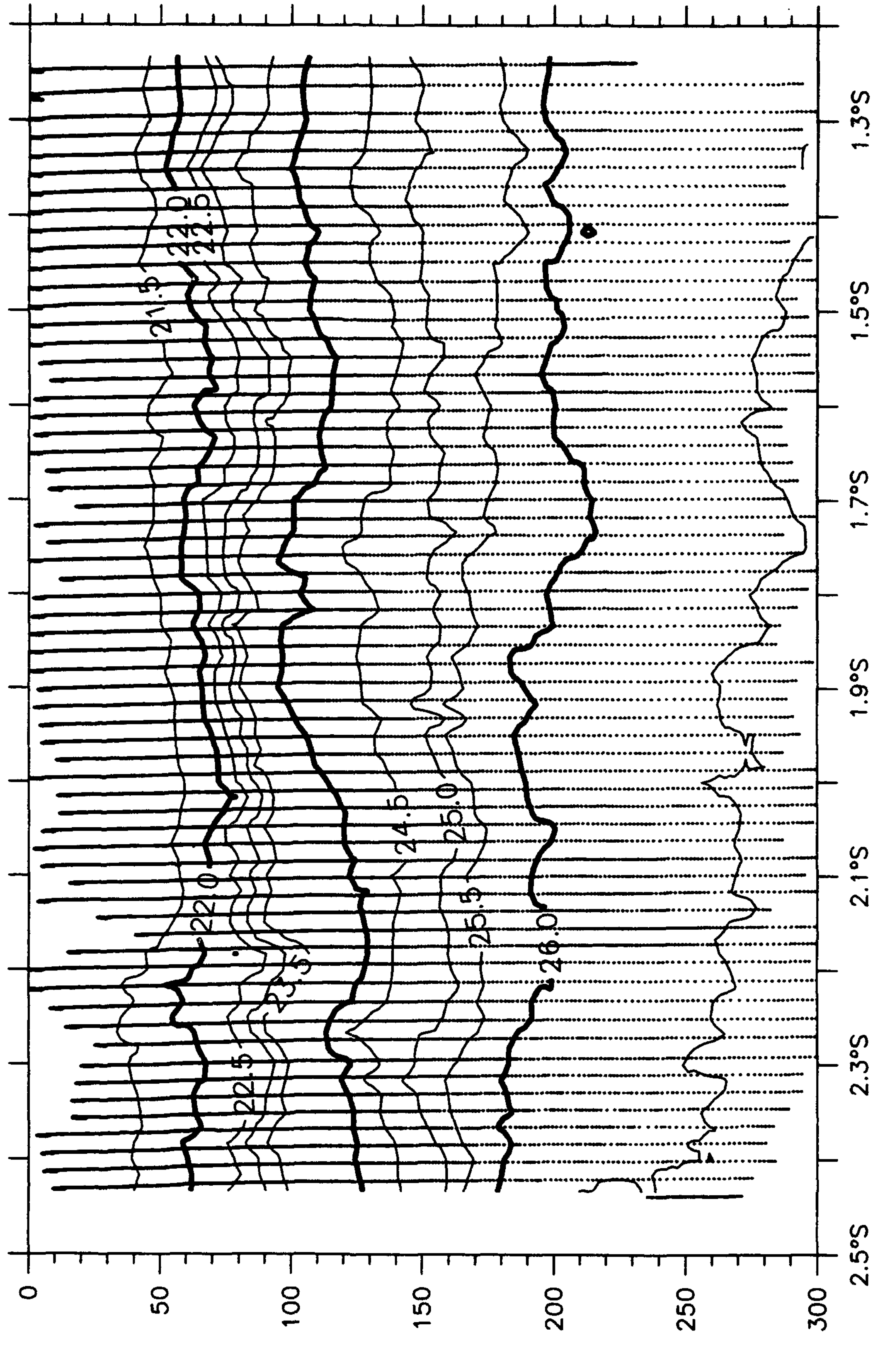
S(psu), N2S, 14 February 1993



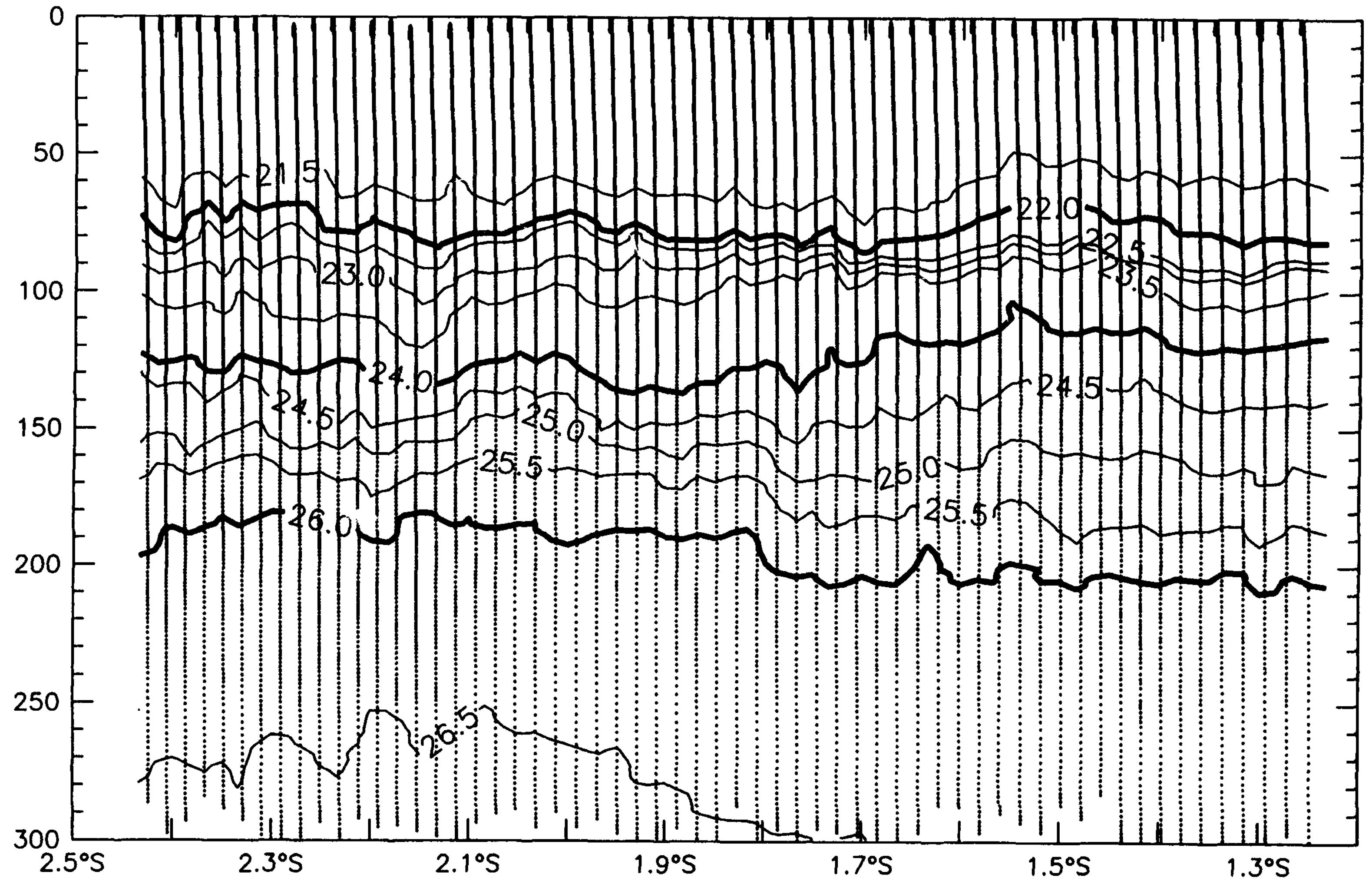
Sigma—t, N2S, 27 January 1993



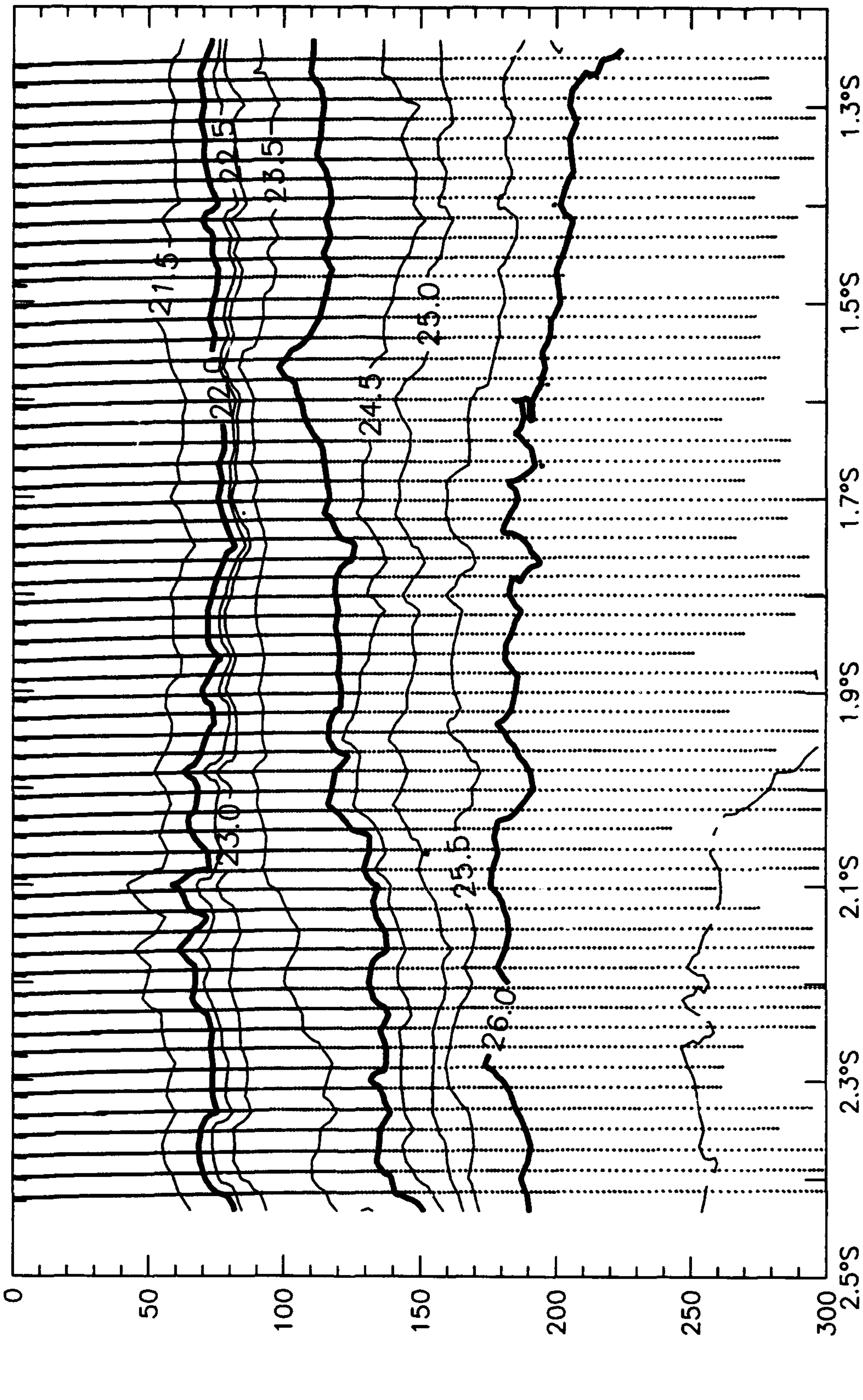
Sigma-t, N2S, 28 January 1993



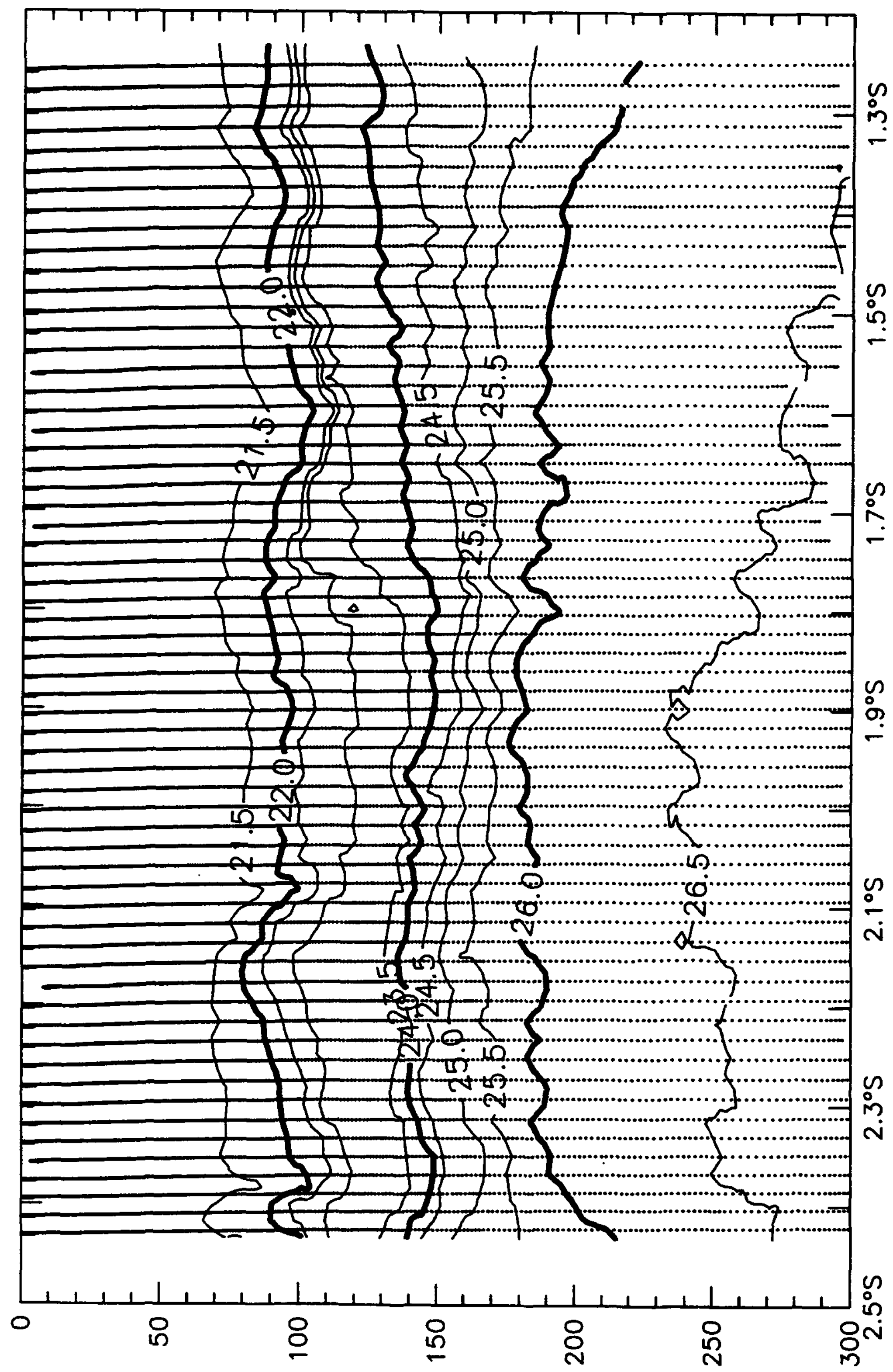
Sigma-t, N2S, 30 January 1993



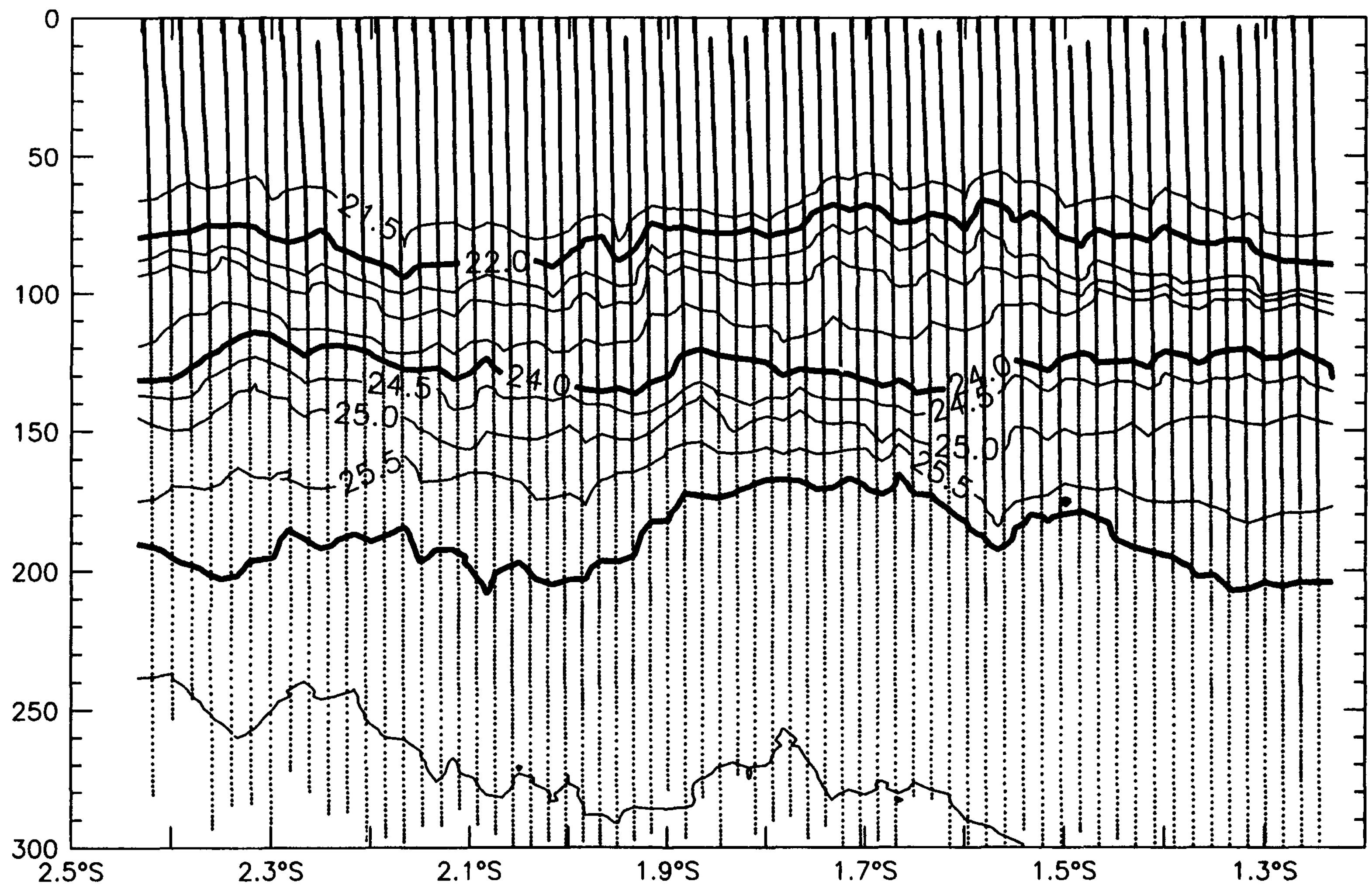
Sigma–t, N2S, 31 January 1993



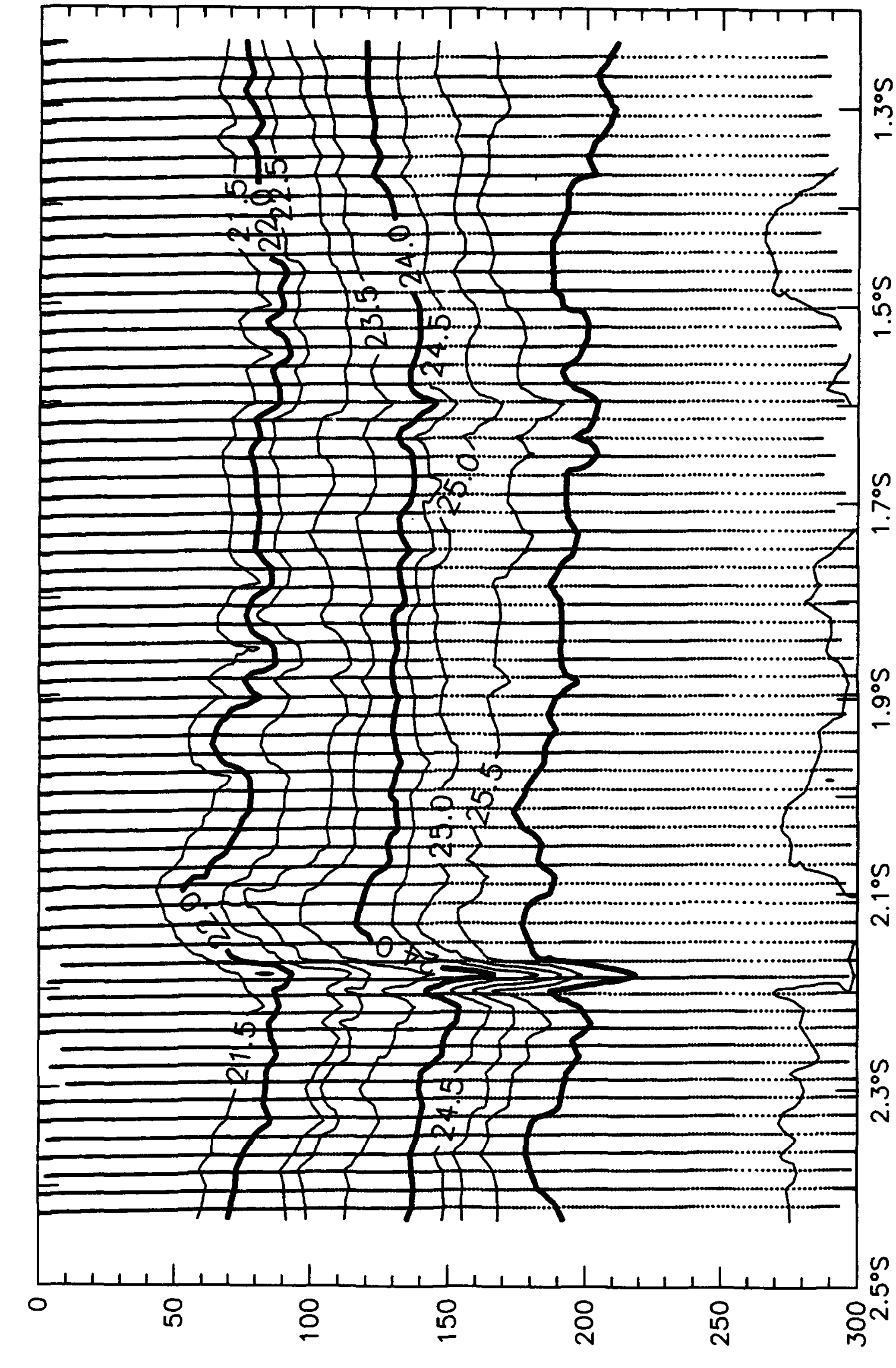
Sigma–t, N2S, 2 February 1993



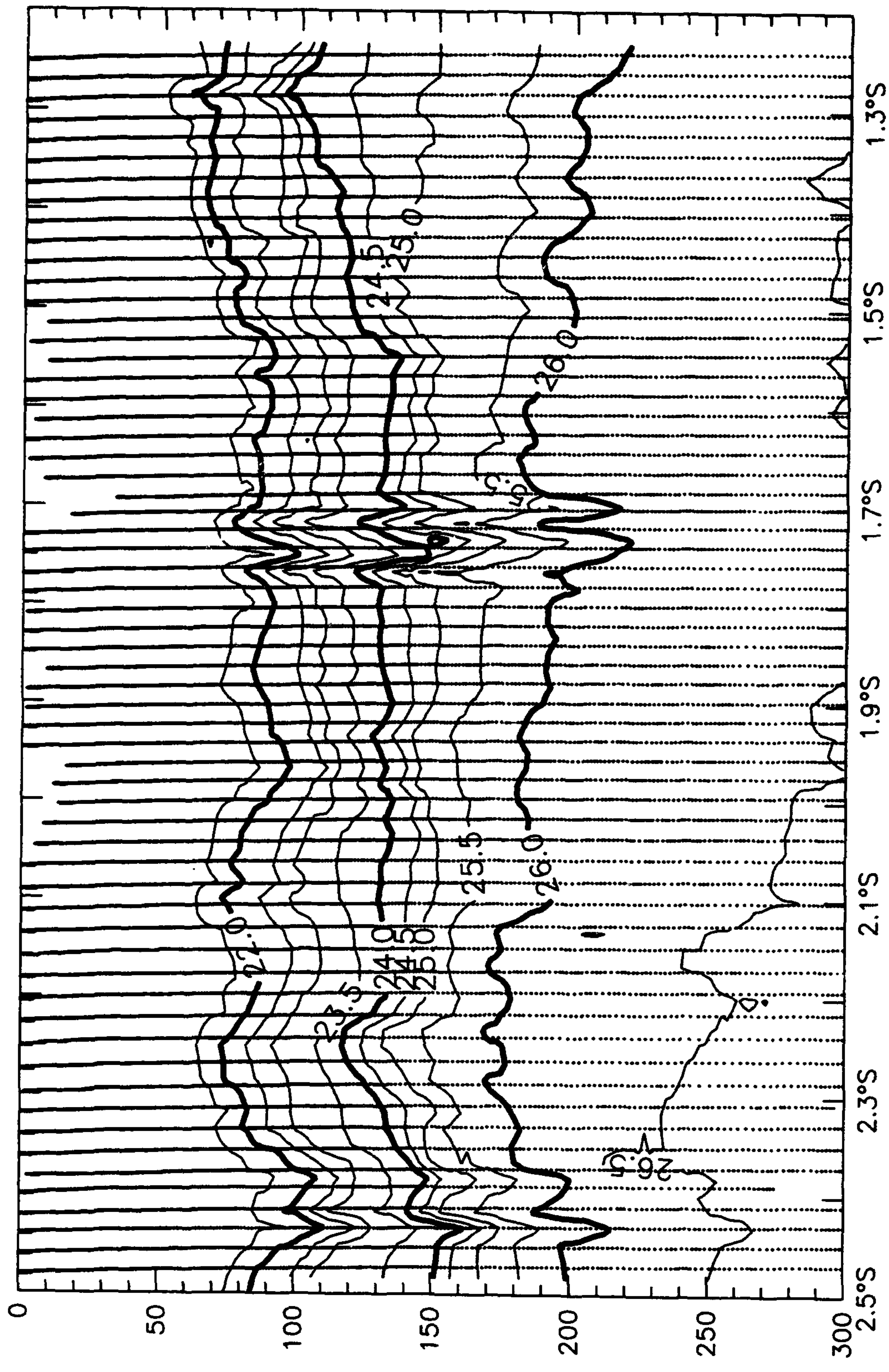
Sigma–t, N2S, 4 February 1993



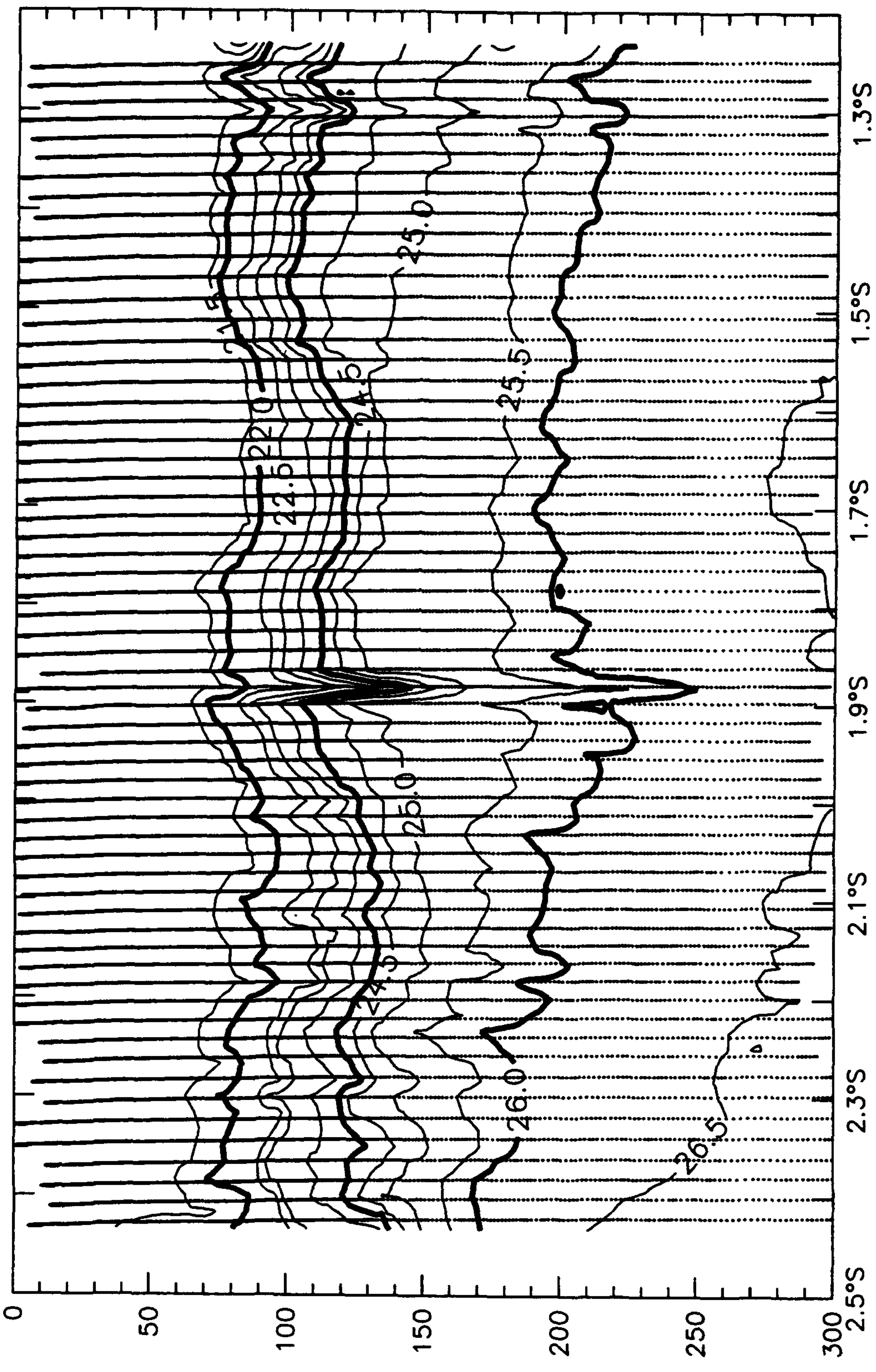
Sigma-t, N2S, 5 February 1993



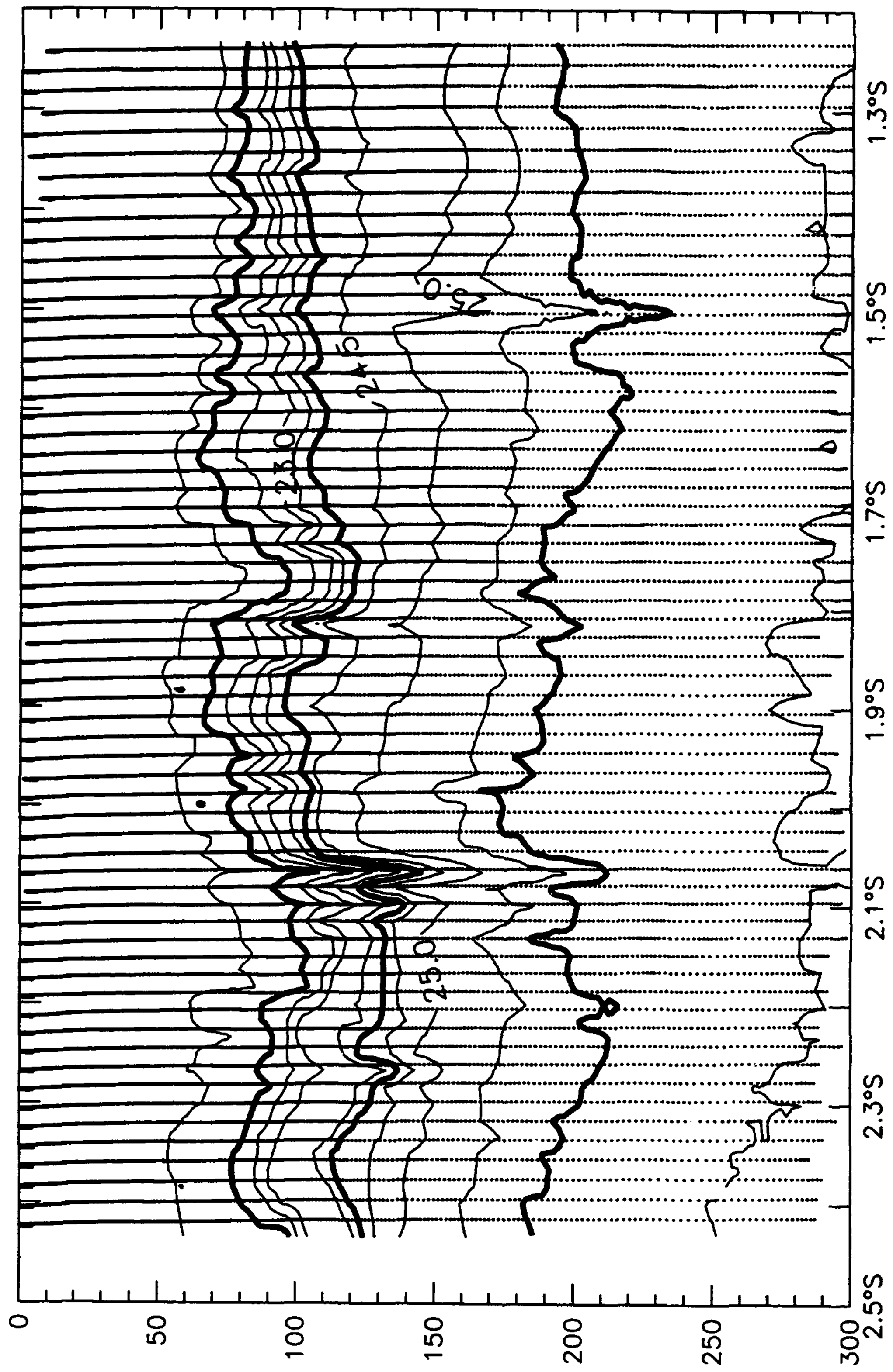
Sigma-t, N2S, 7 February 1993



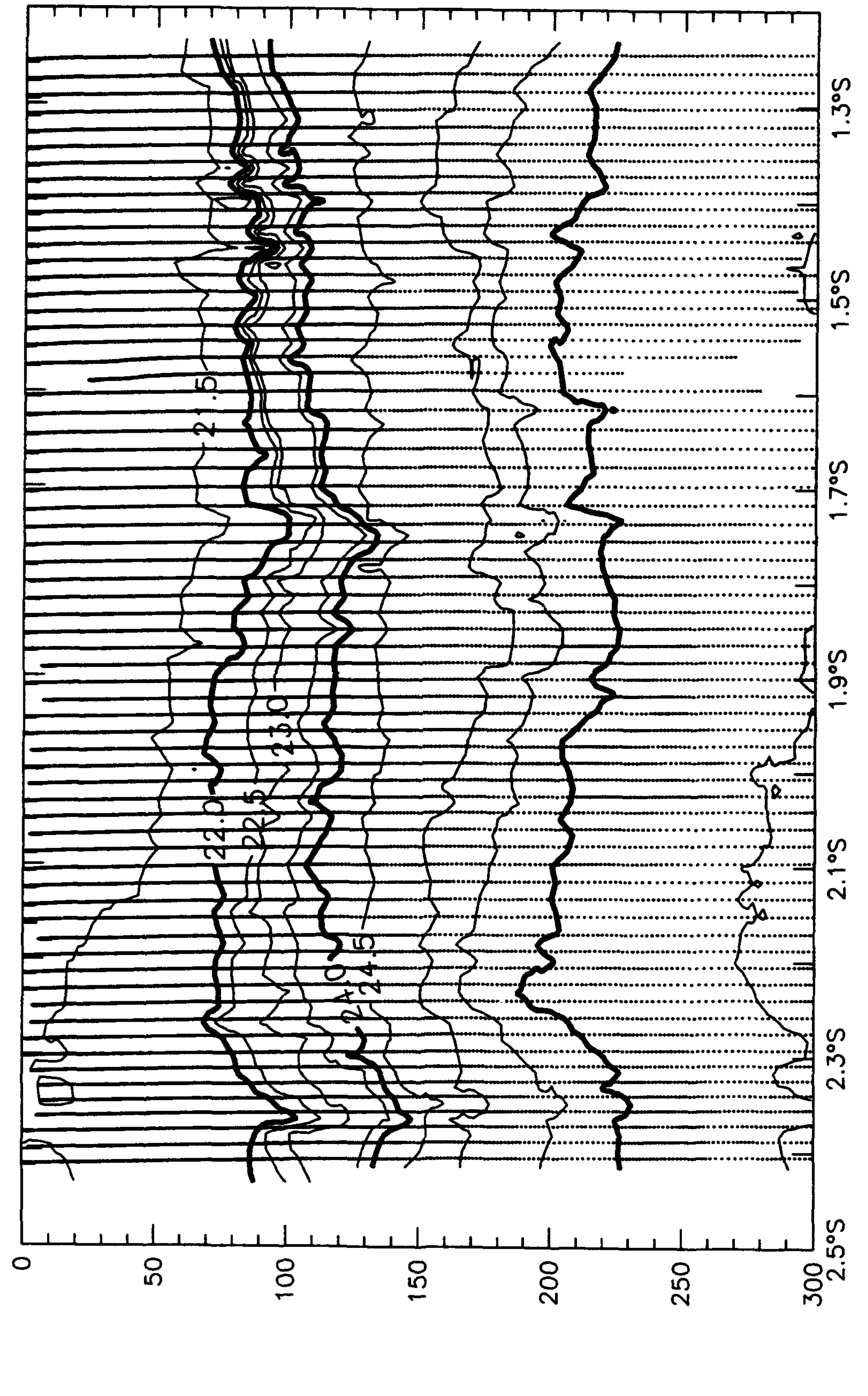
Sigma-t, N2S, 9 February 1993



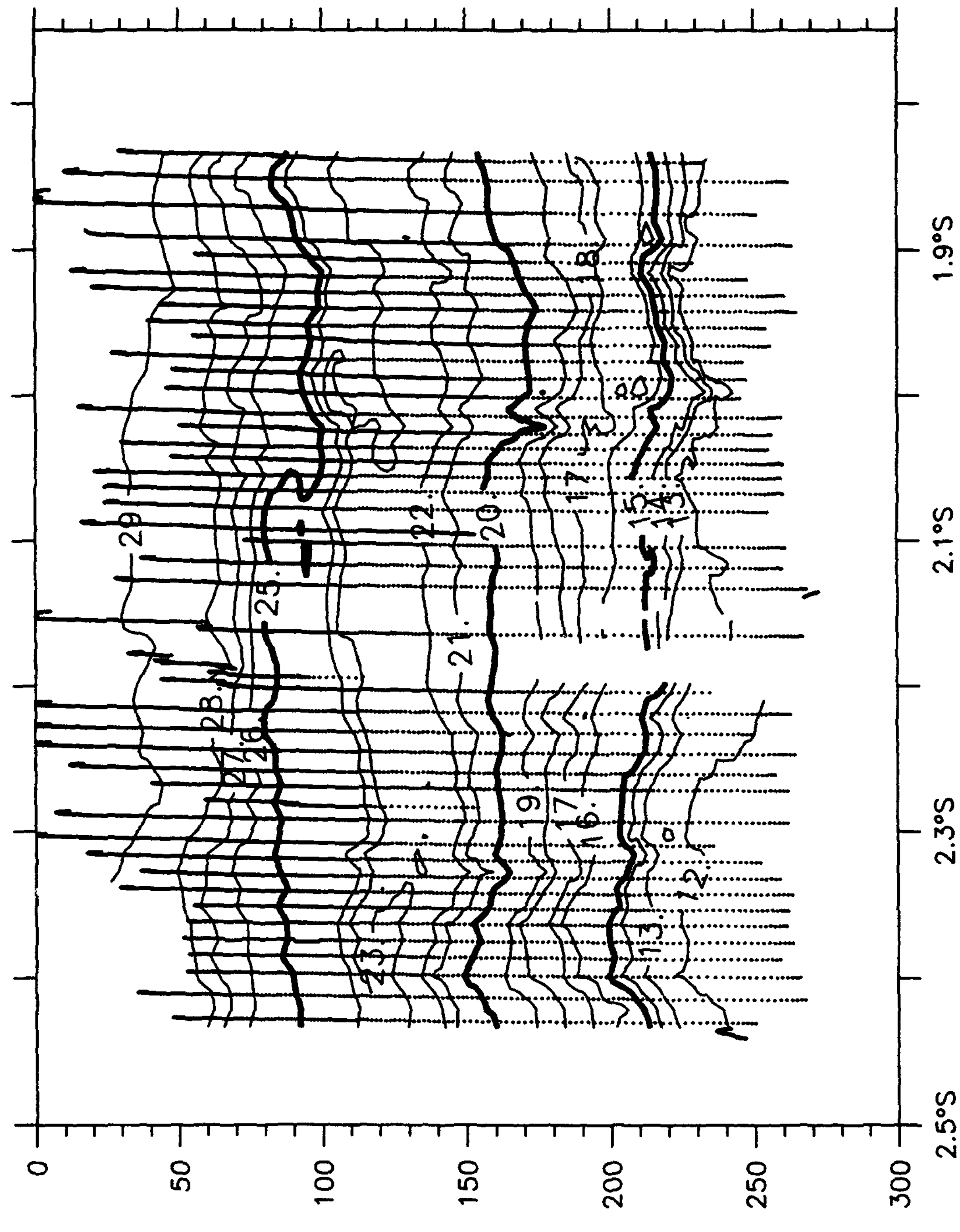
Sigma–t, N2S, 10 February 1993



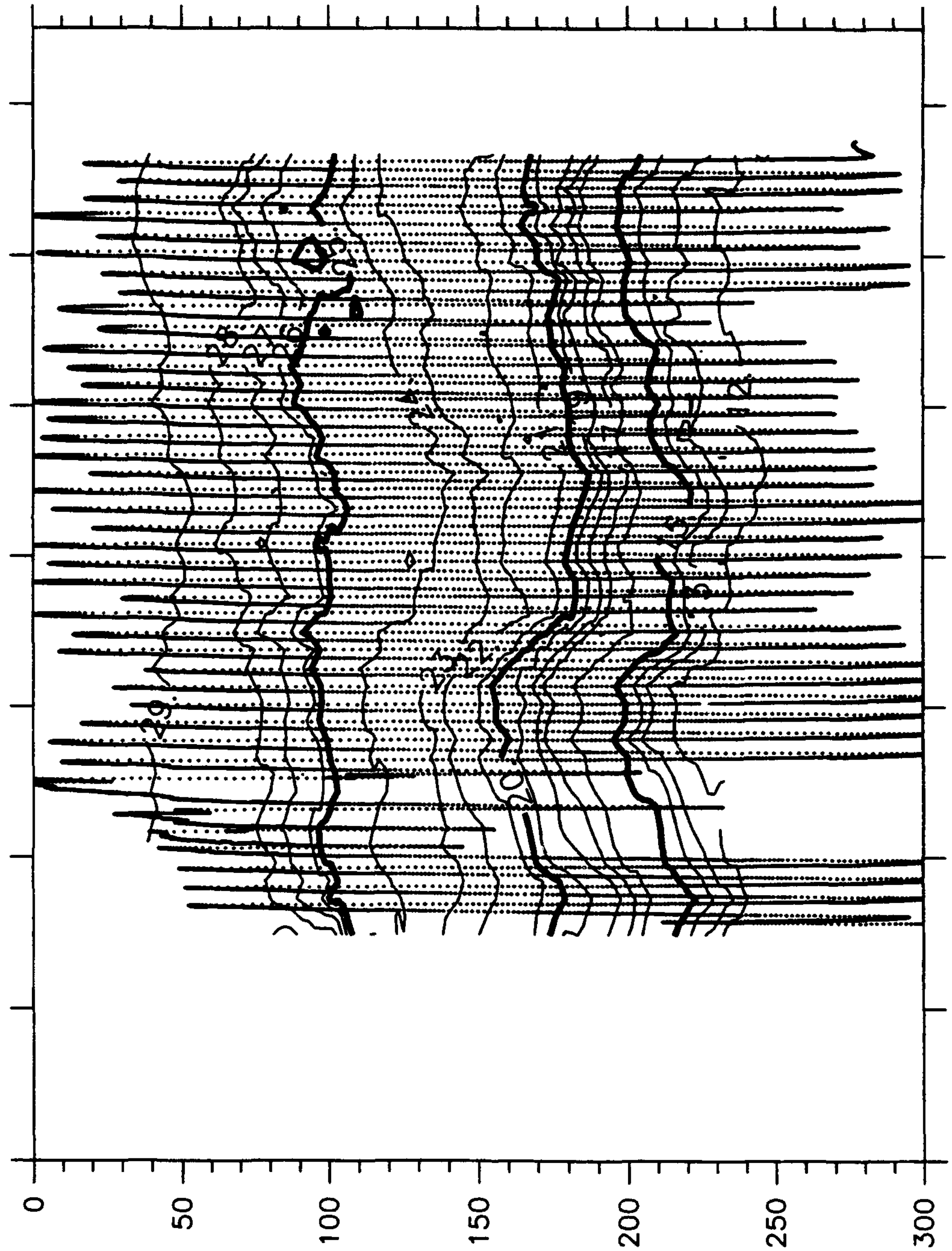
Sigma-t, N2S, 12 February 1993



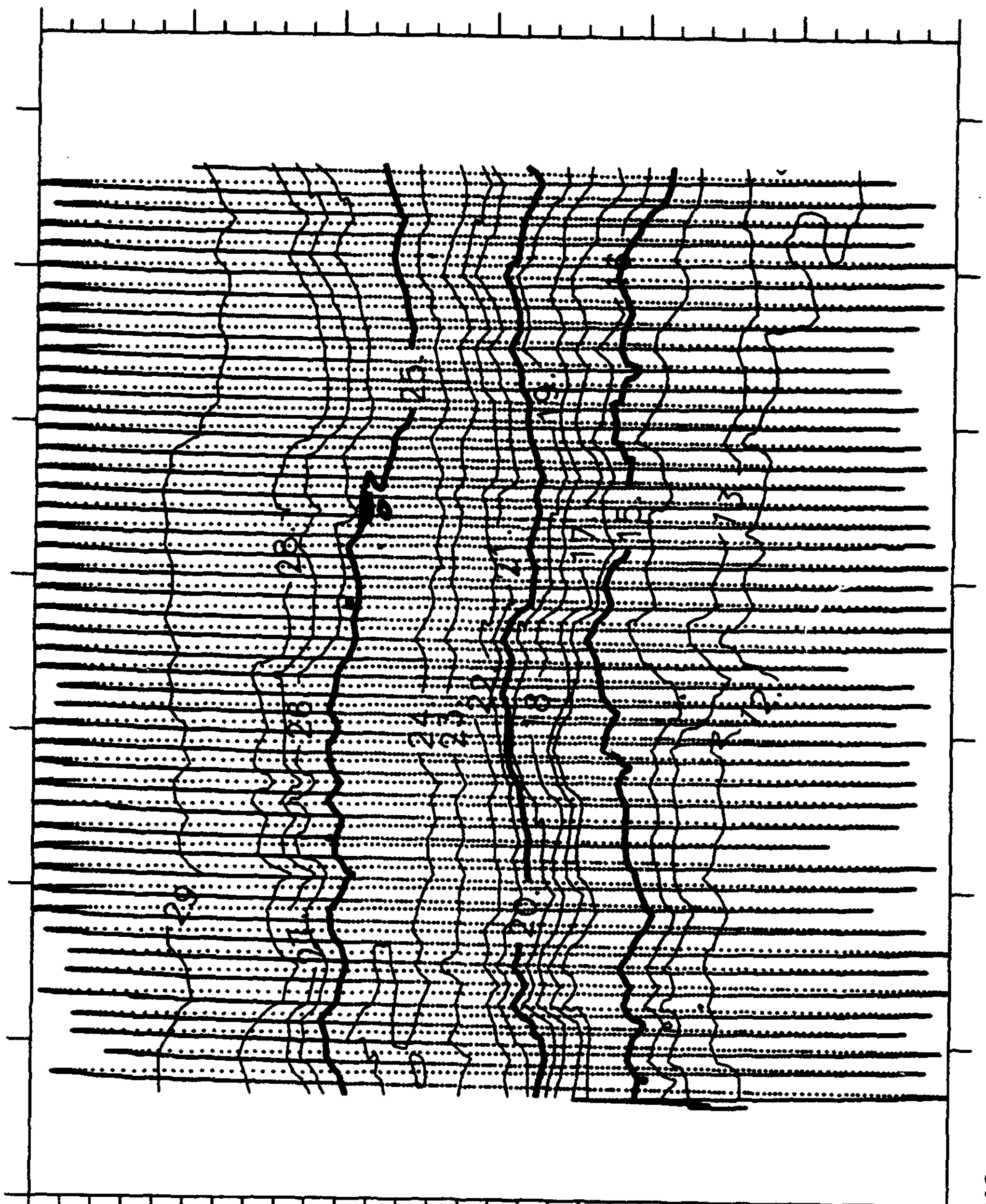
Sigma–t, N2S, 14 February 1993



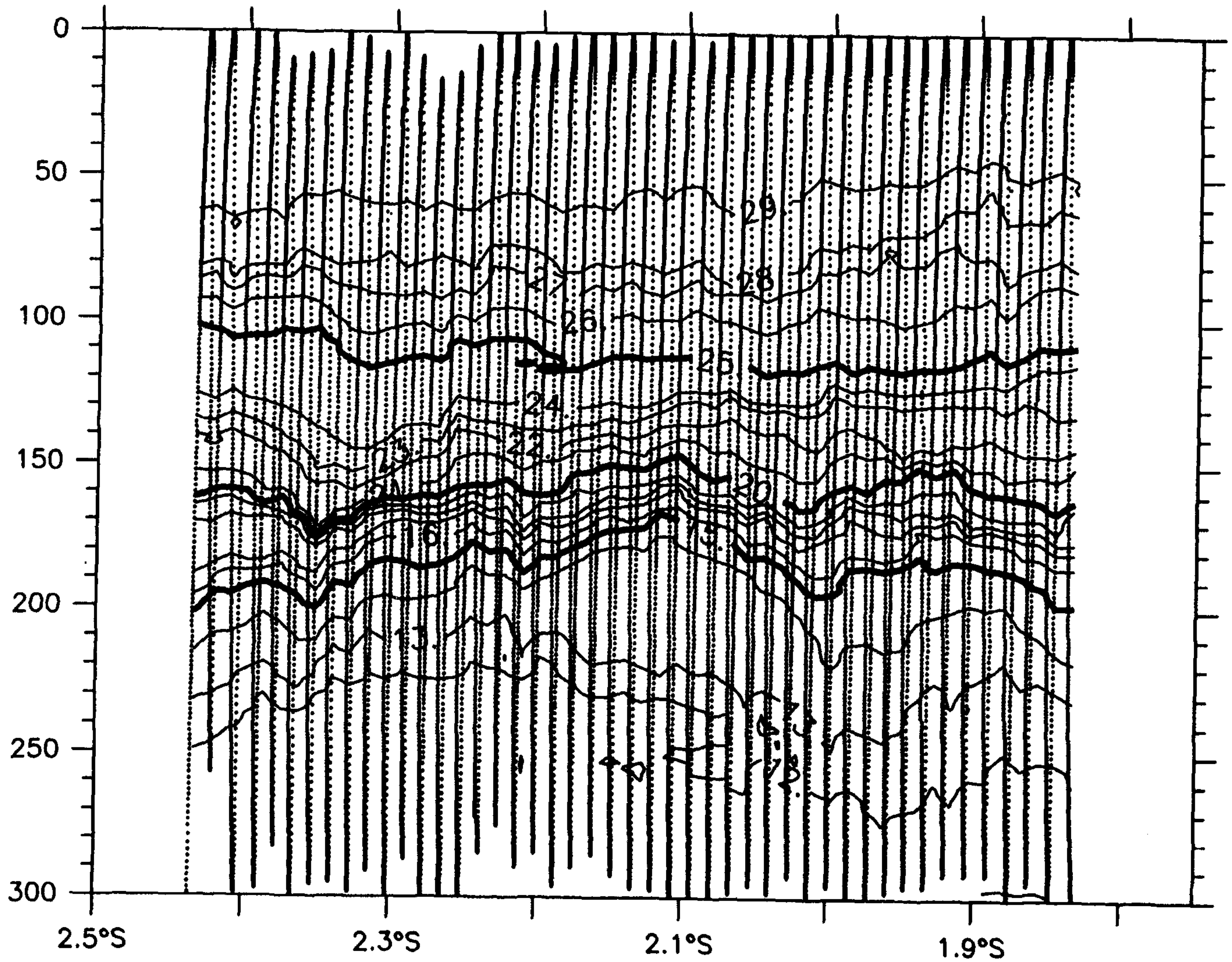
T(°C), S2W, 27 January 1993



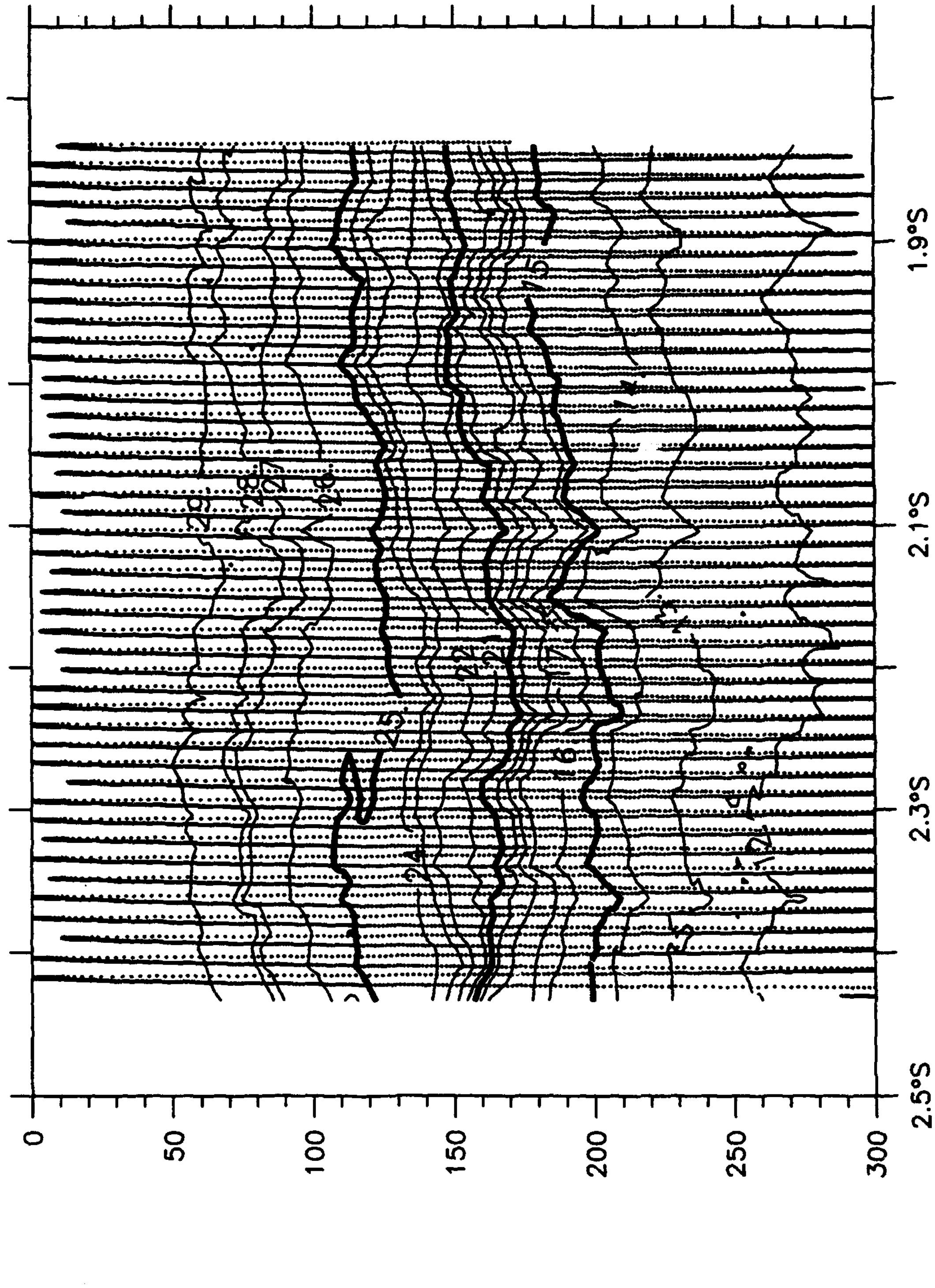
T(°C), S2W, 29 January 1993



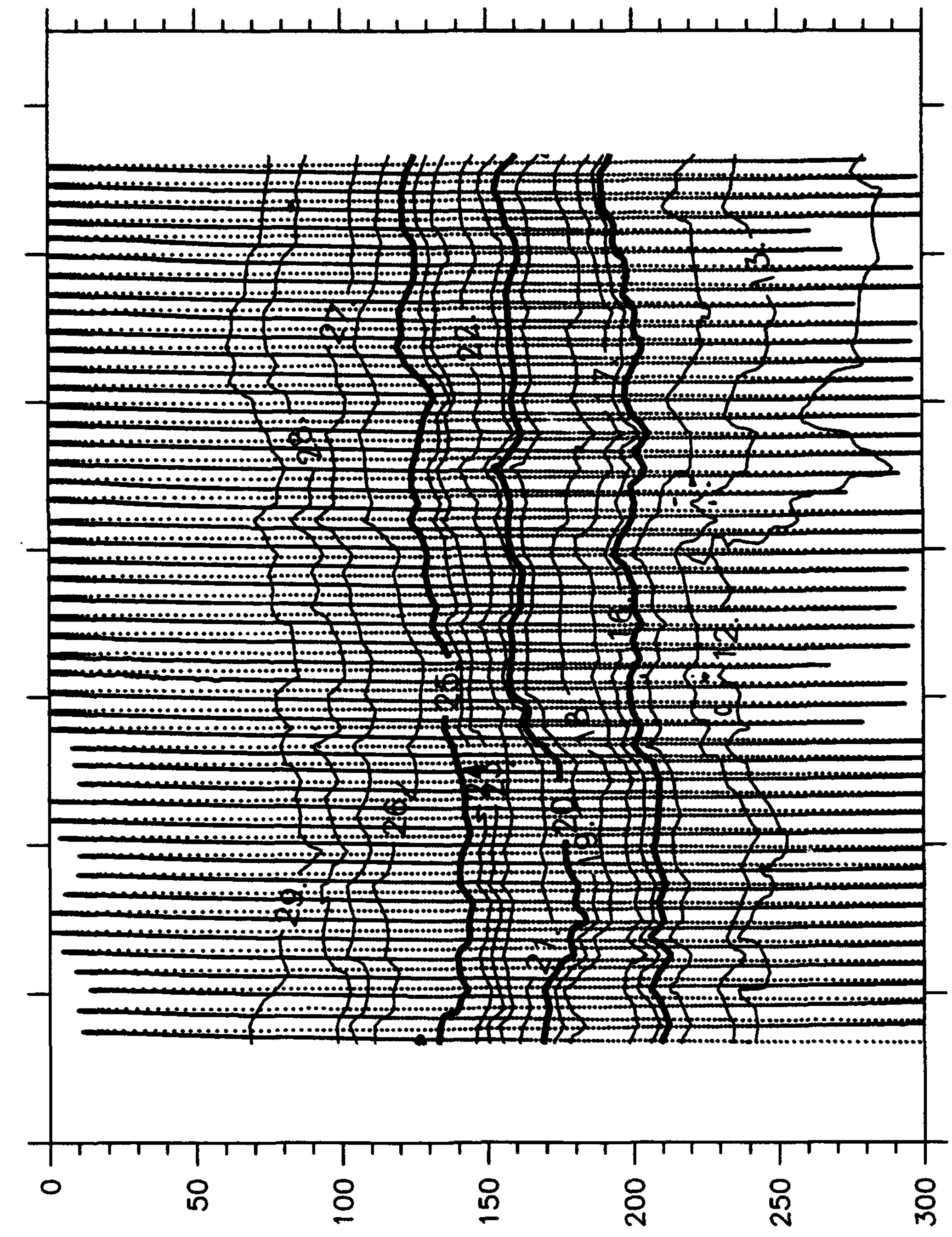
T(°C), S2W, 30 January 1993



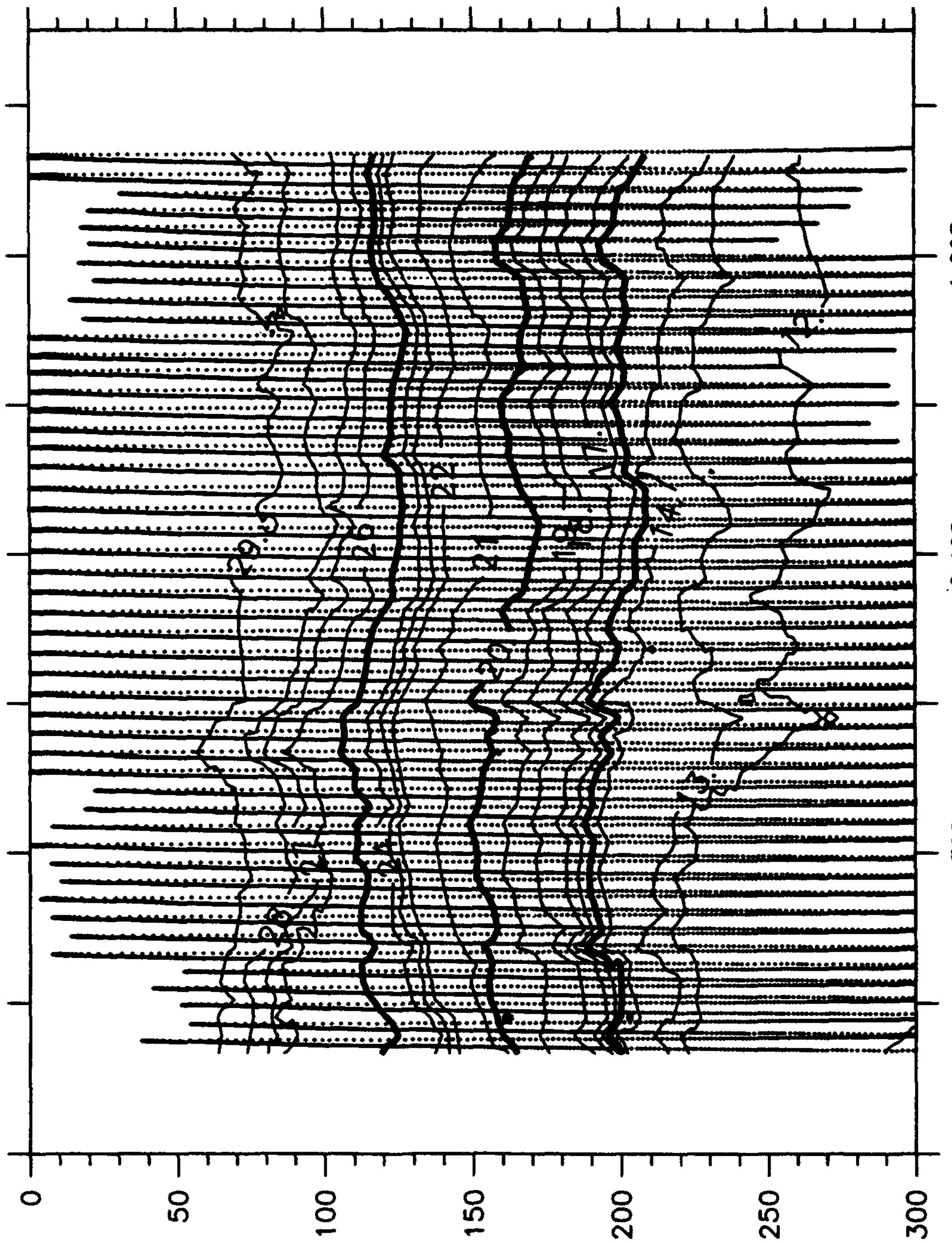
T(°C), S2W, 01 Febuary 1993



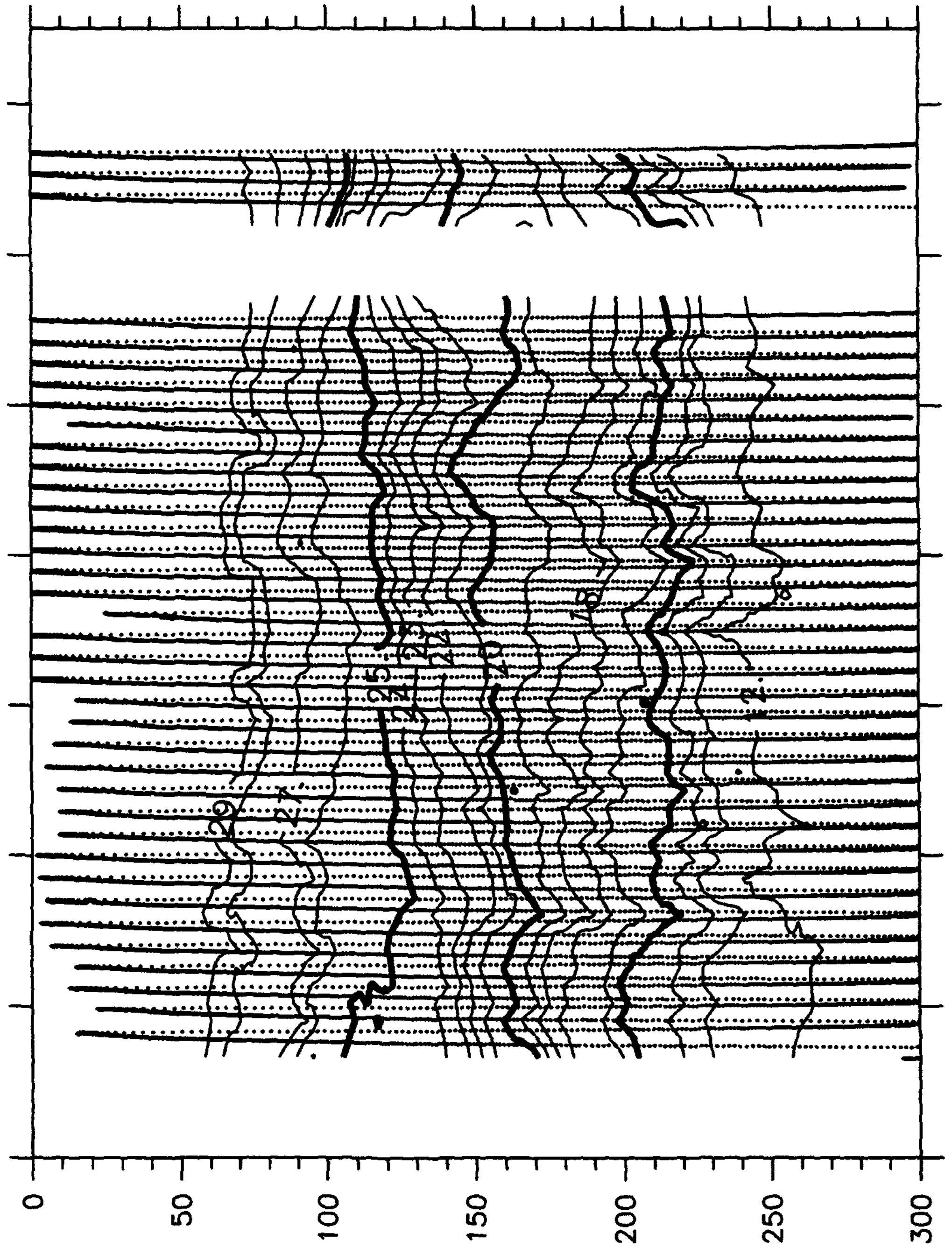
T(°C), S2W, 2 February 1993



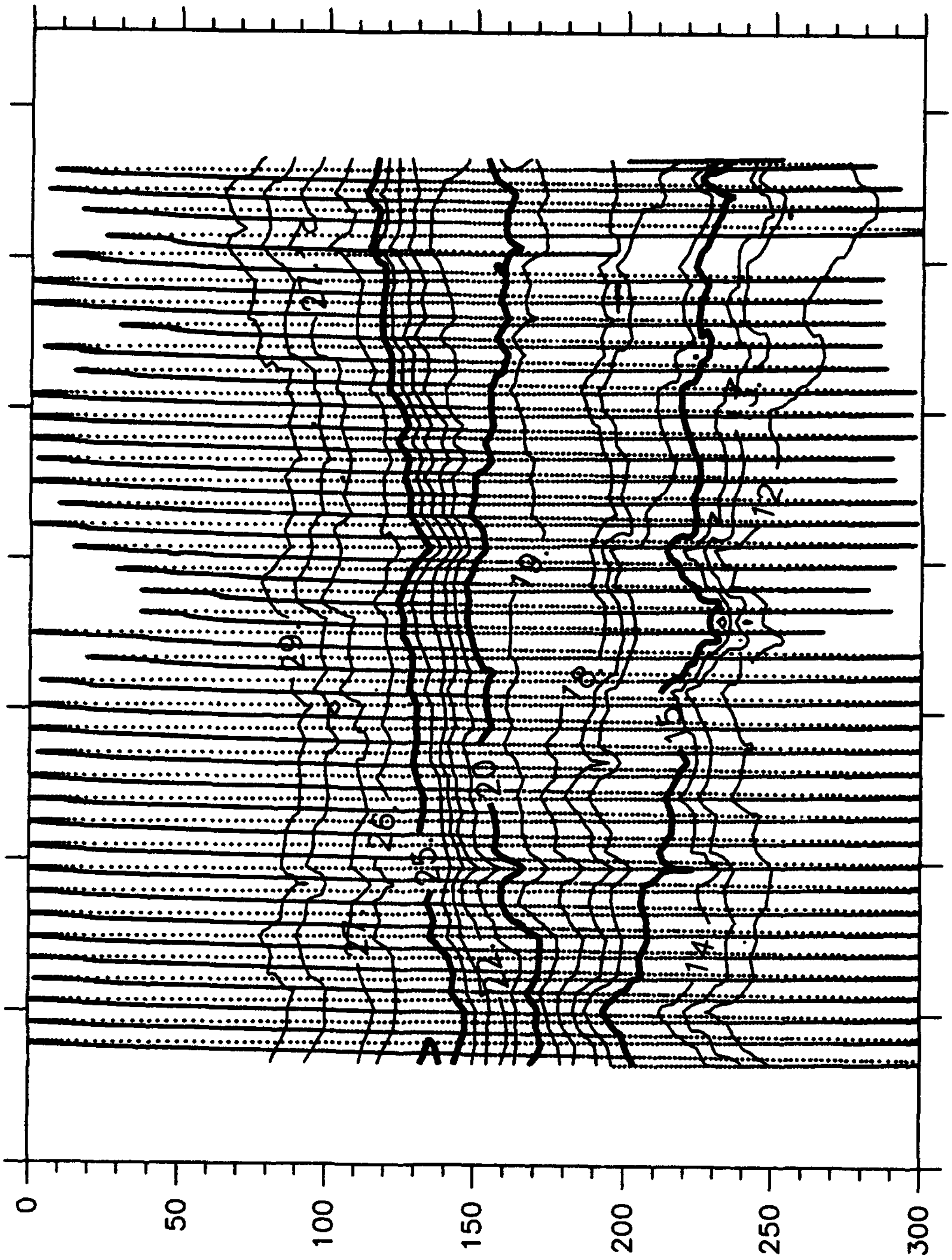
T(°C), S2W, 4 February 1993



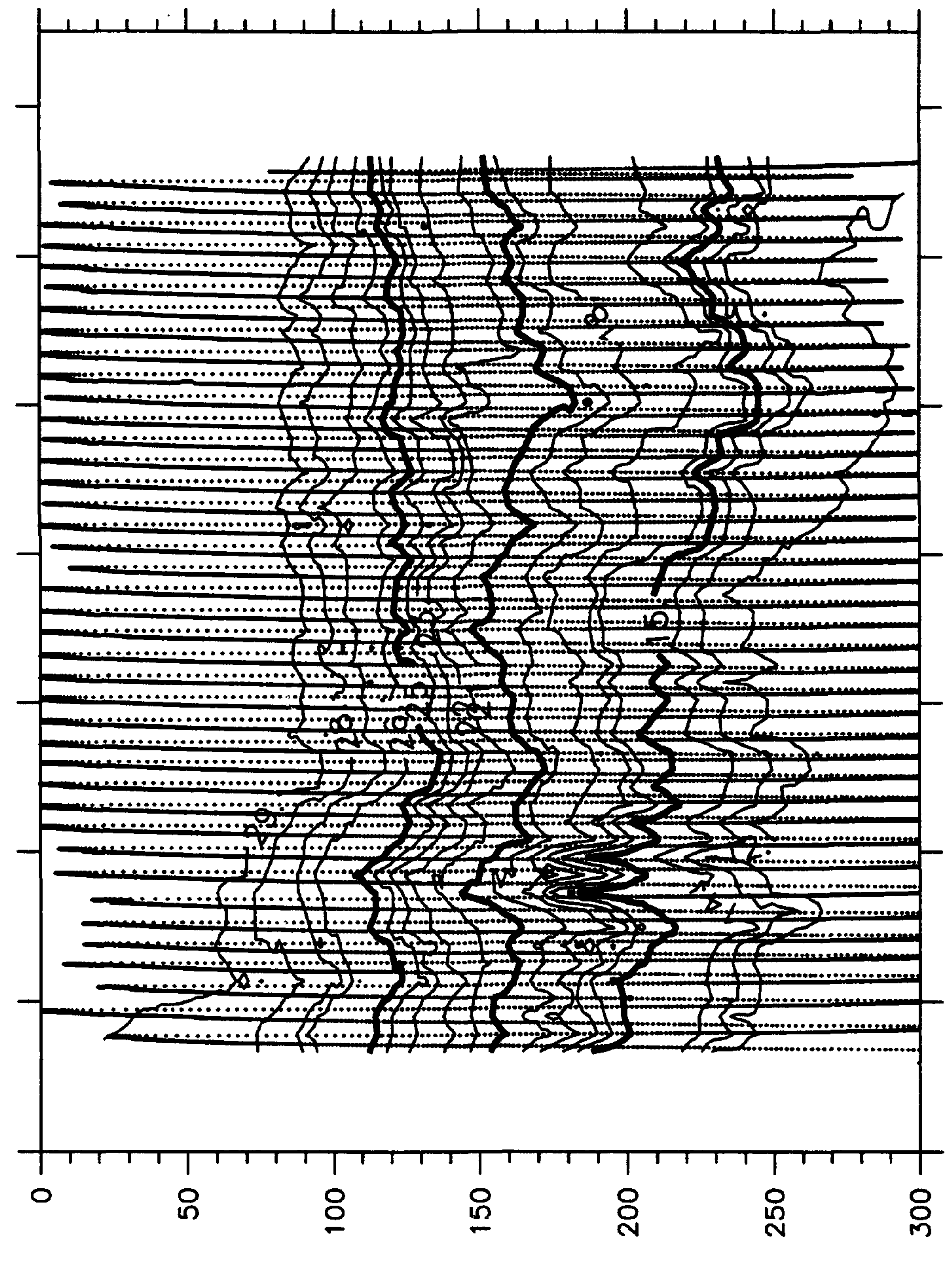
T(°C), S2W, 6 February 1993



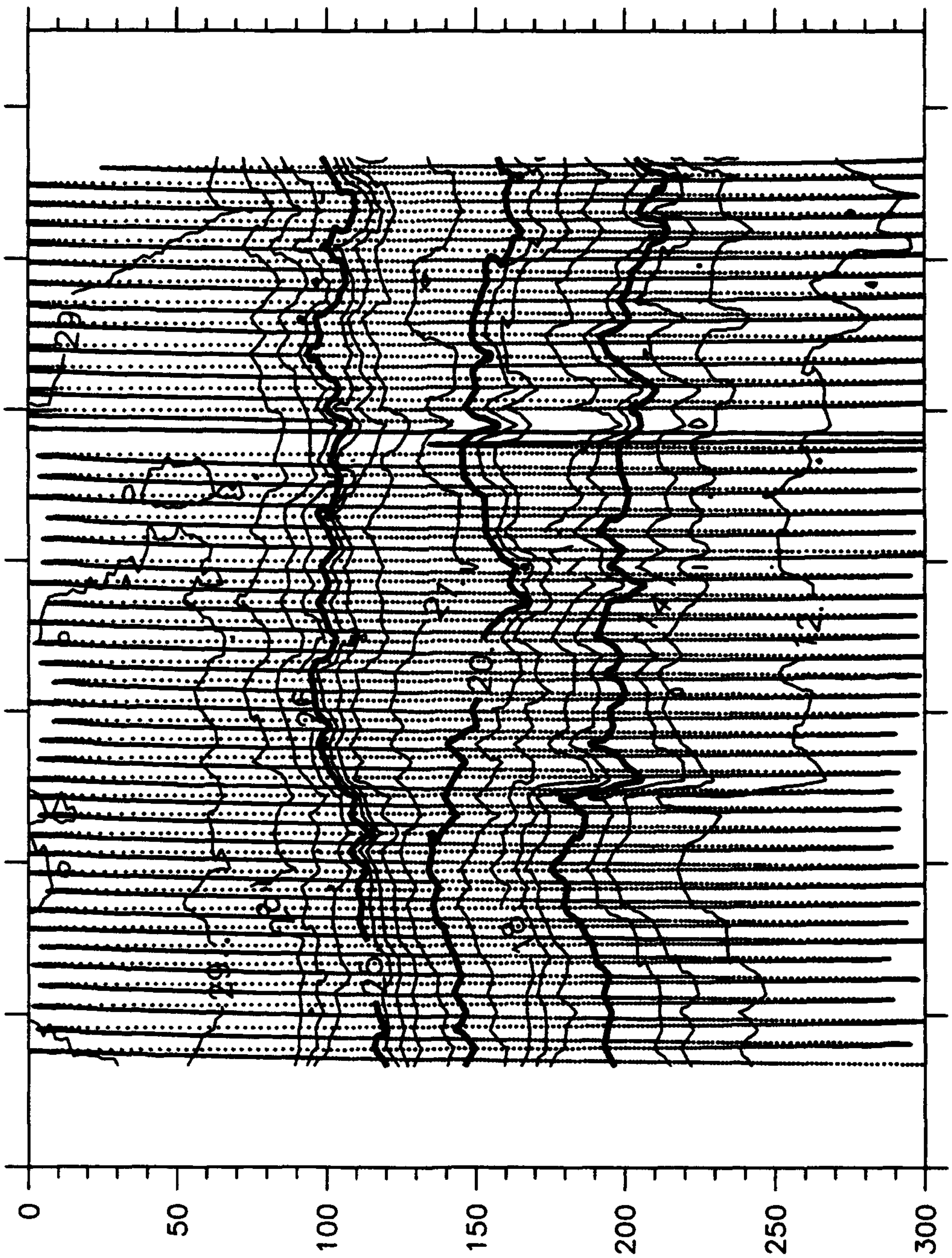
T(°C), S2W, 8 February 1993



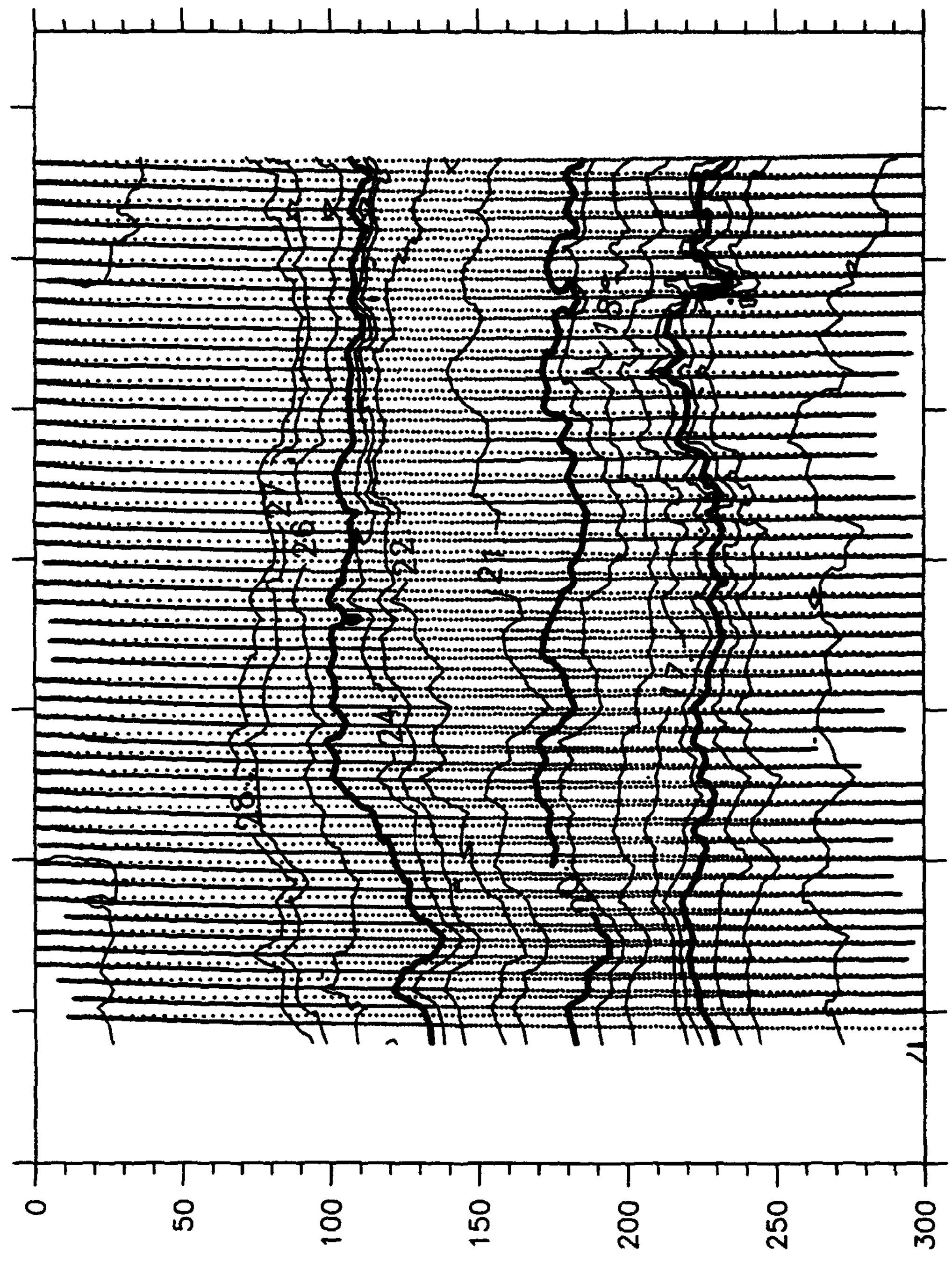
T(°C), S2W, 9 February 1993



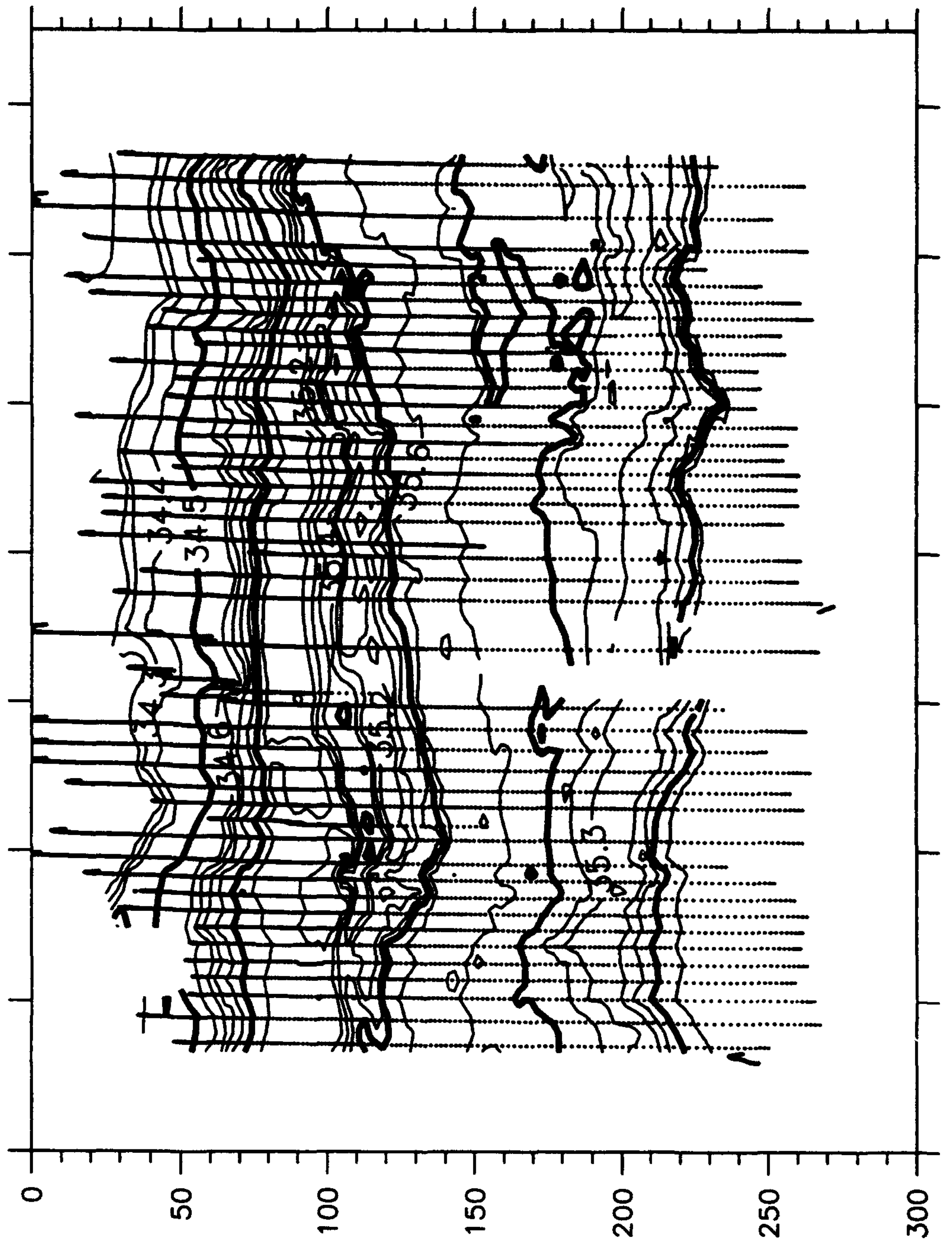
T(°C), S2W, 11 February 1993



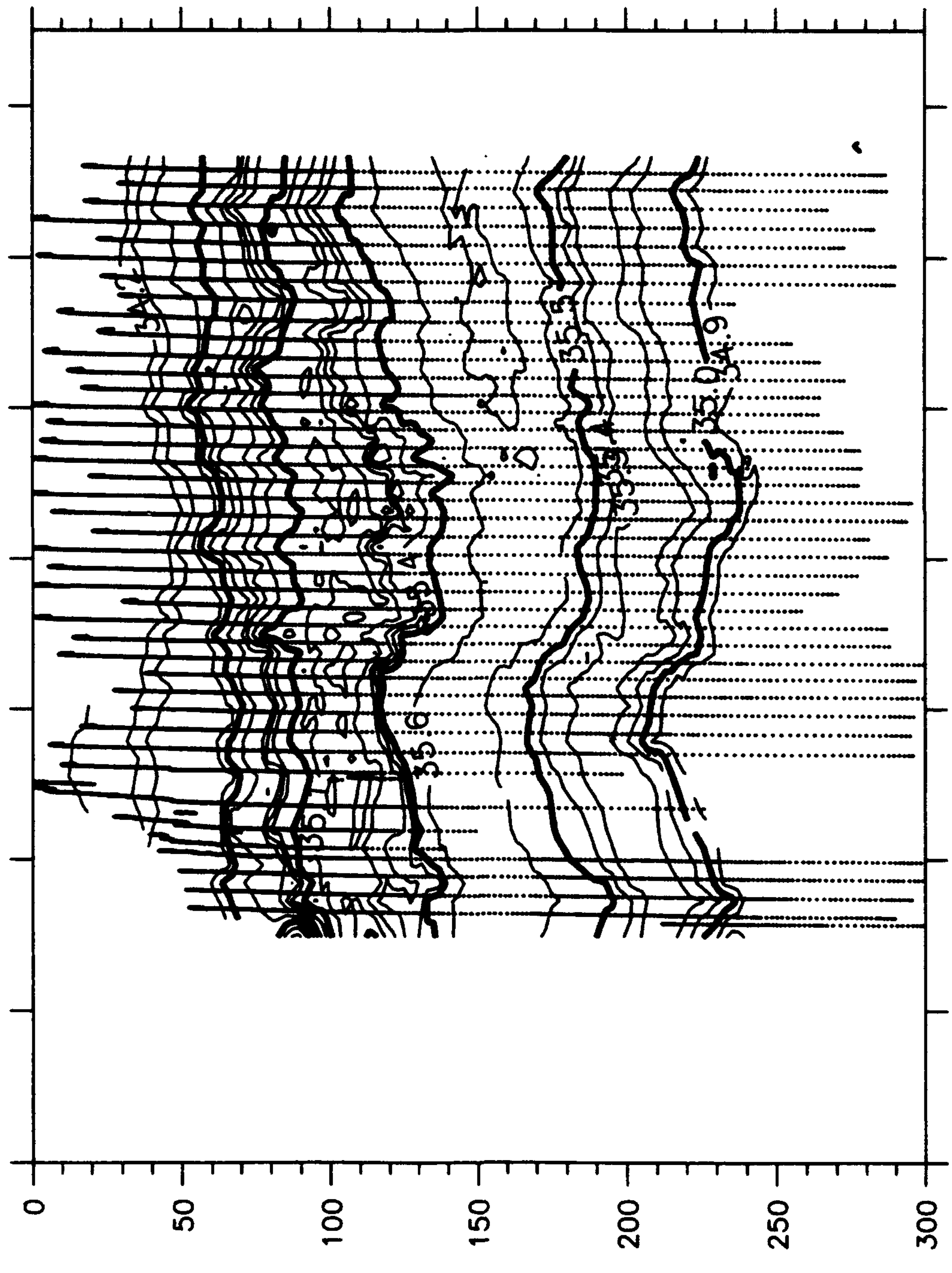
T(°C), S2W, 12–13 February 1993



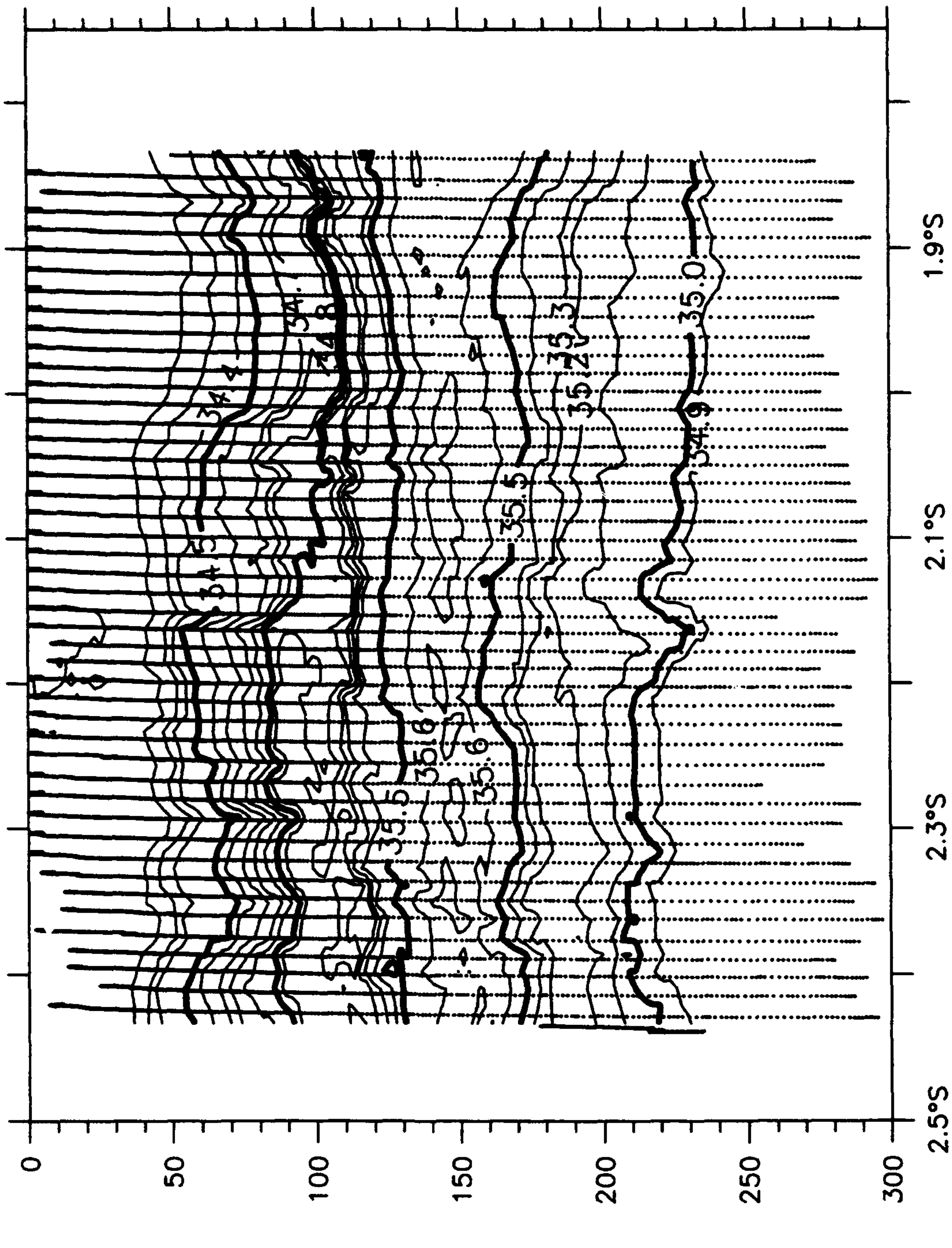
T(°C), S2W, 14 February 1993



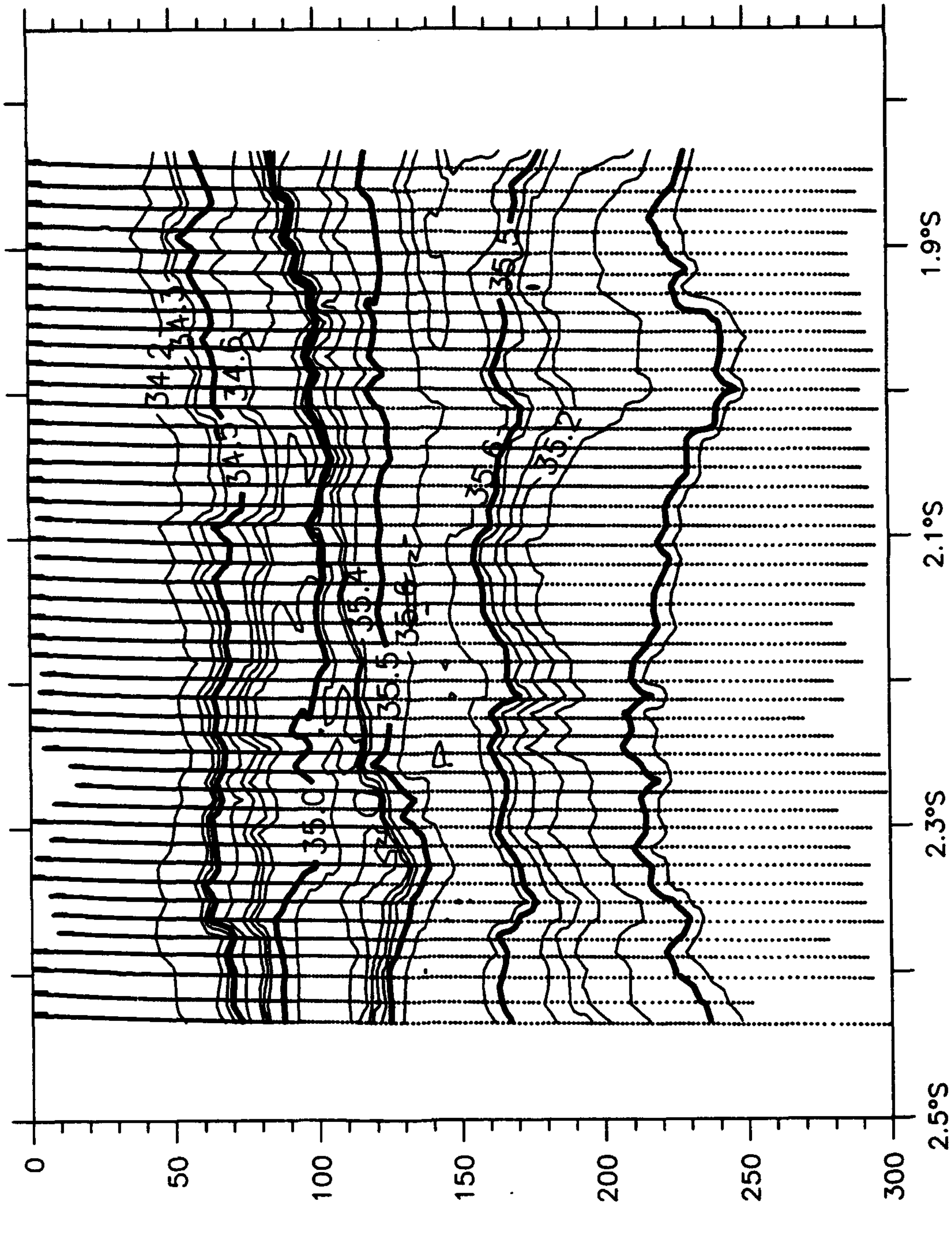
S(psu), S2W, 27 January 1993



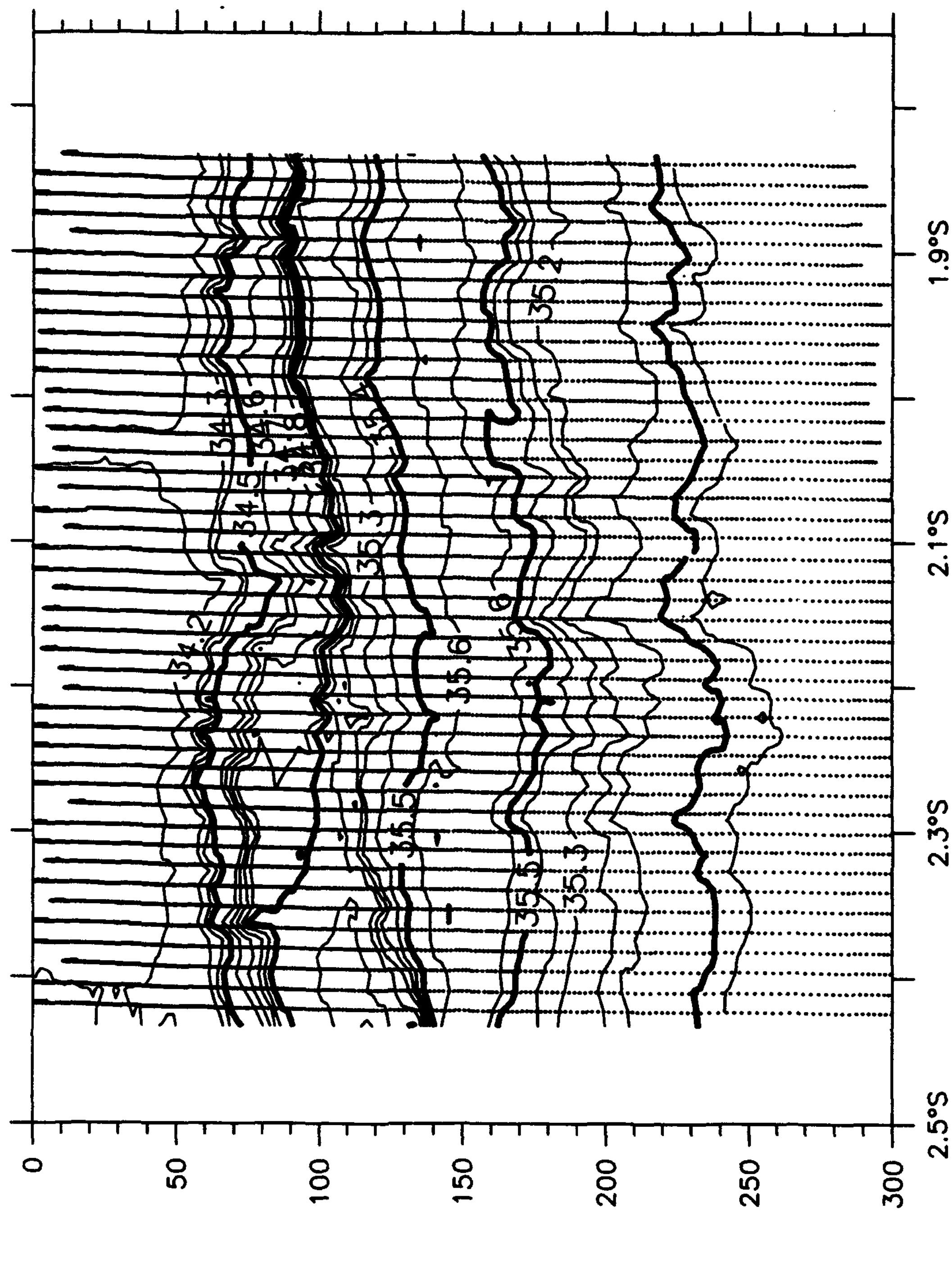
S(psu), S2W, 29 January 1993



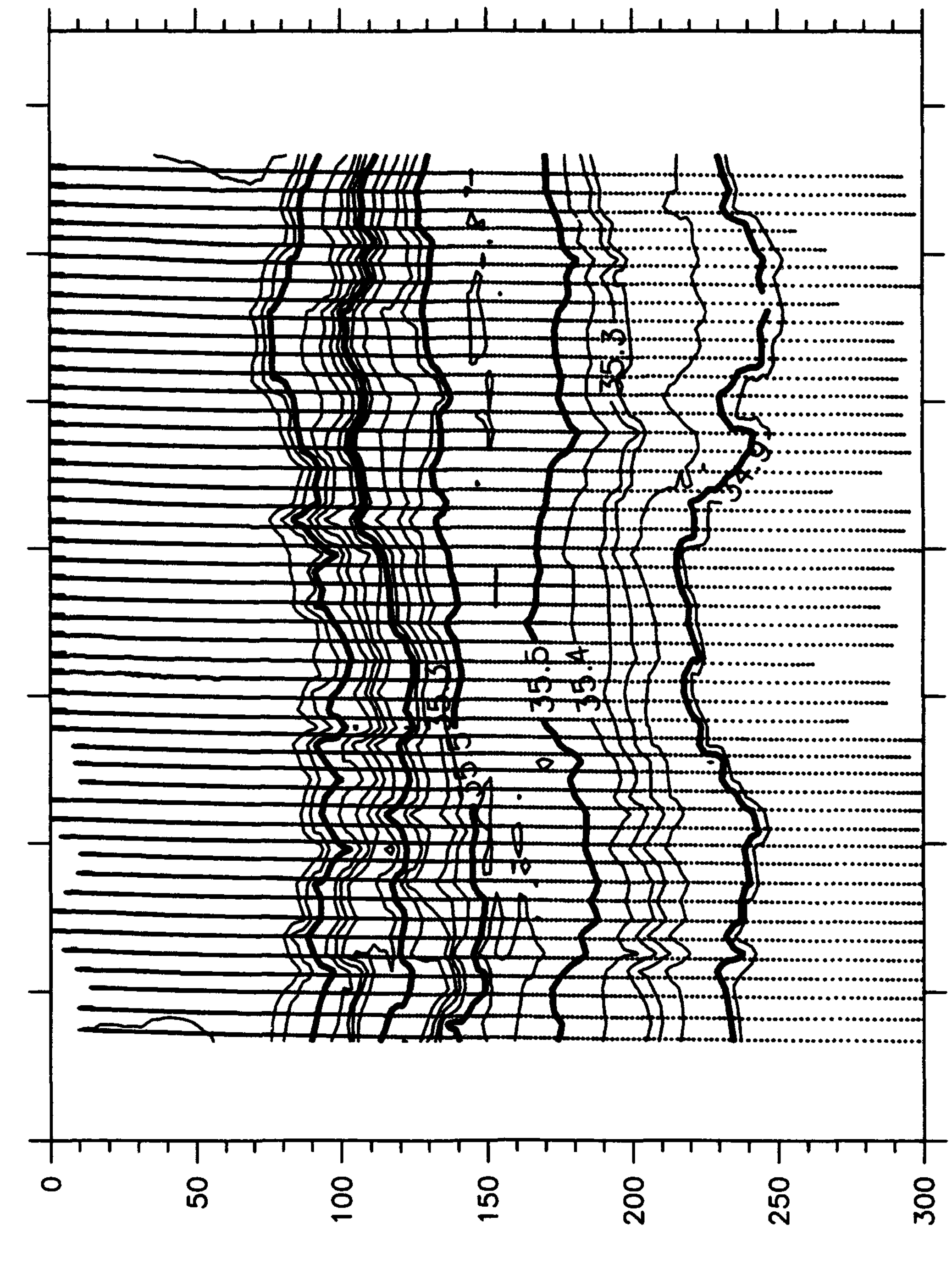
S(psu), S2W, 30 January 1993



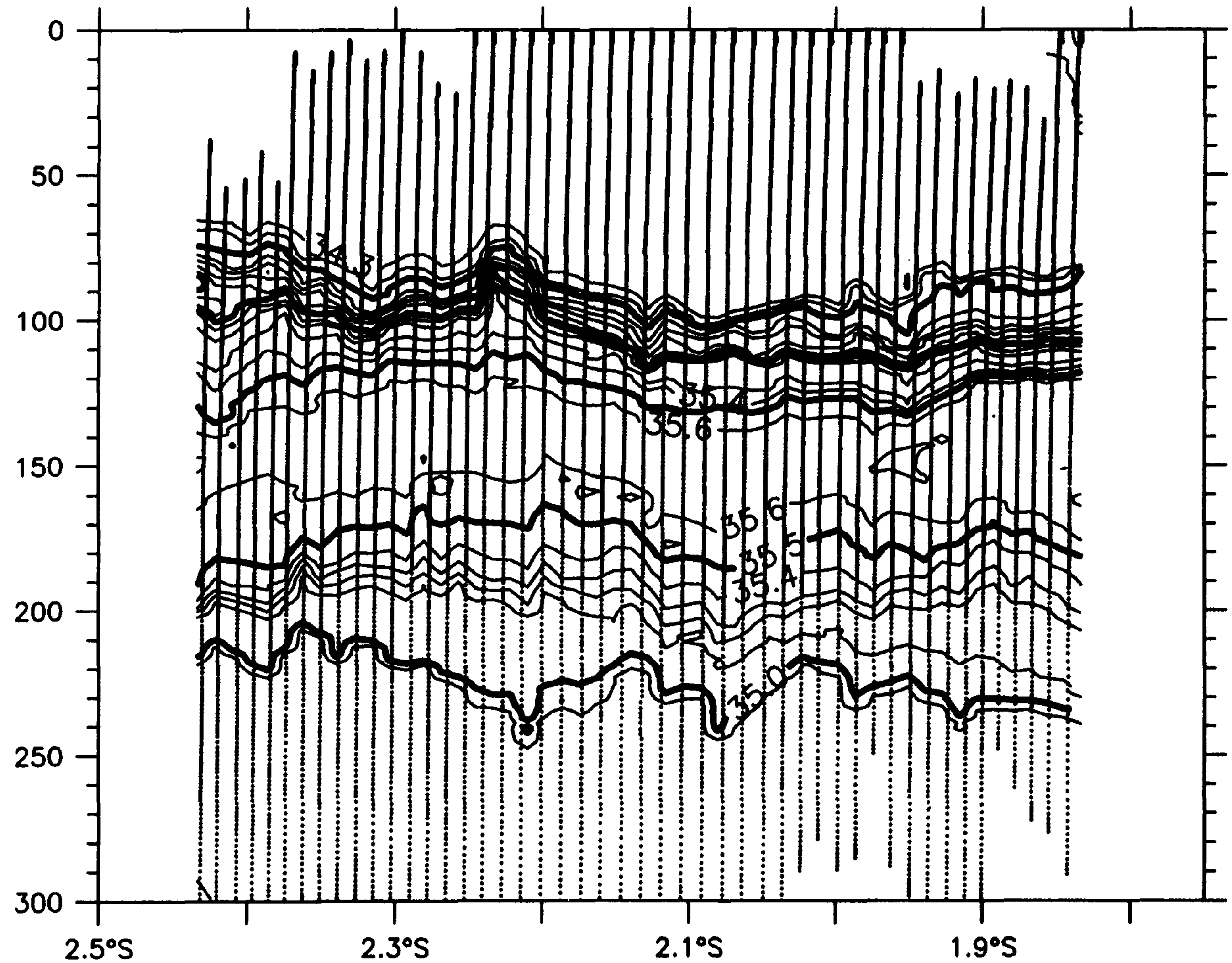
S(psu), S2W, 1 February 1993



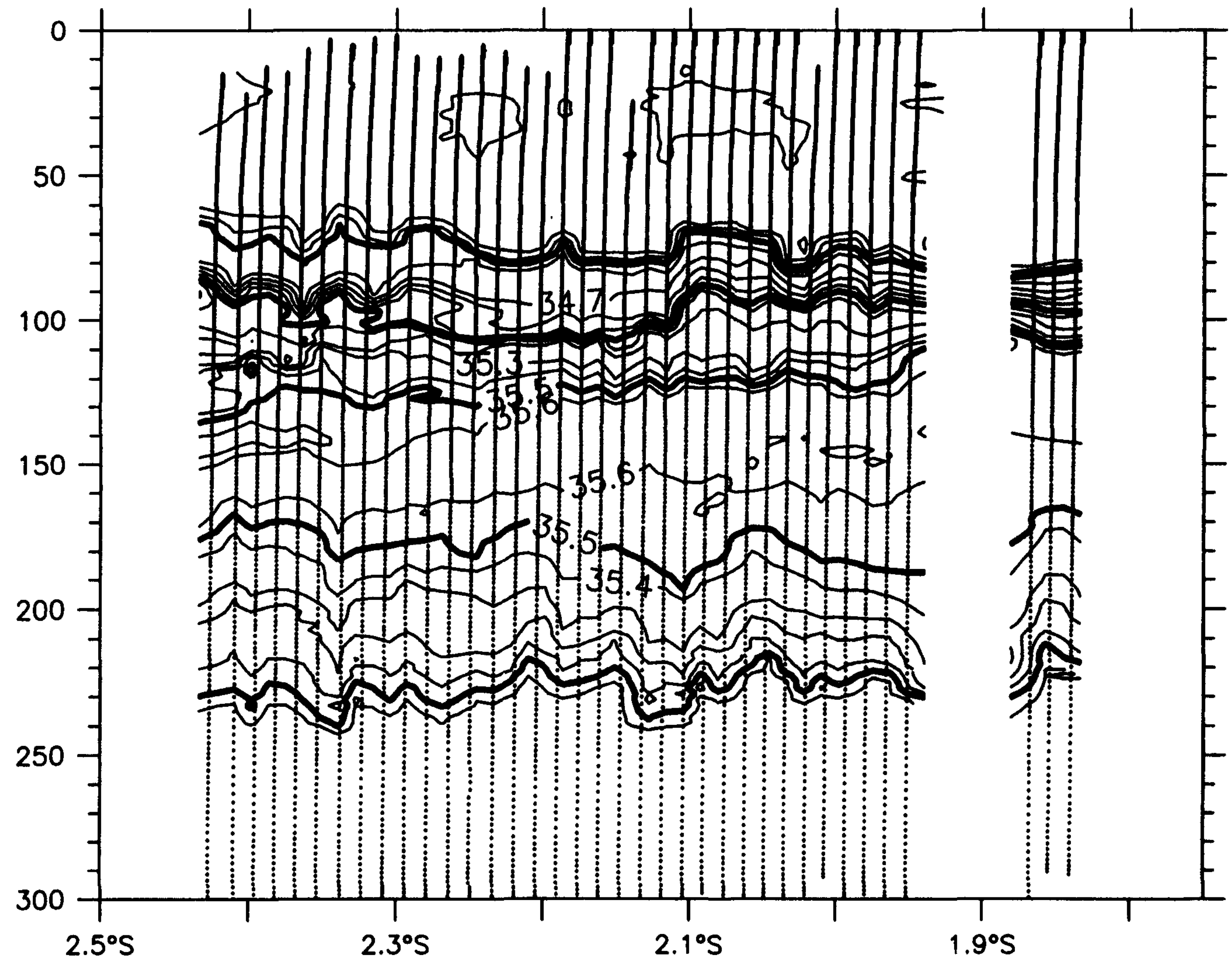
S(psu), S2W, 2 February 1993



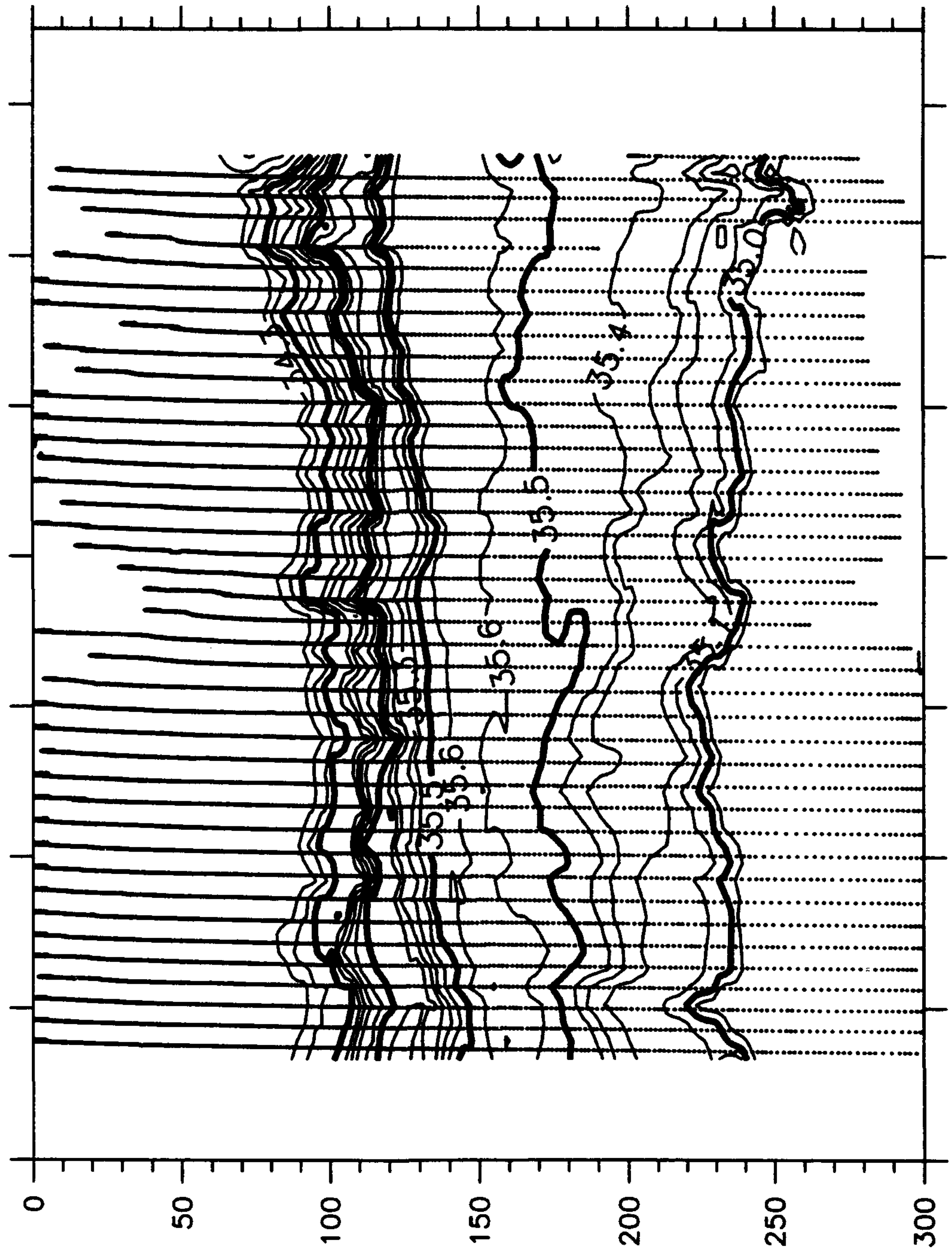
S(psu), S2W, 4 February 1993



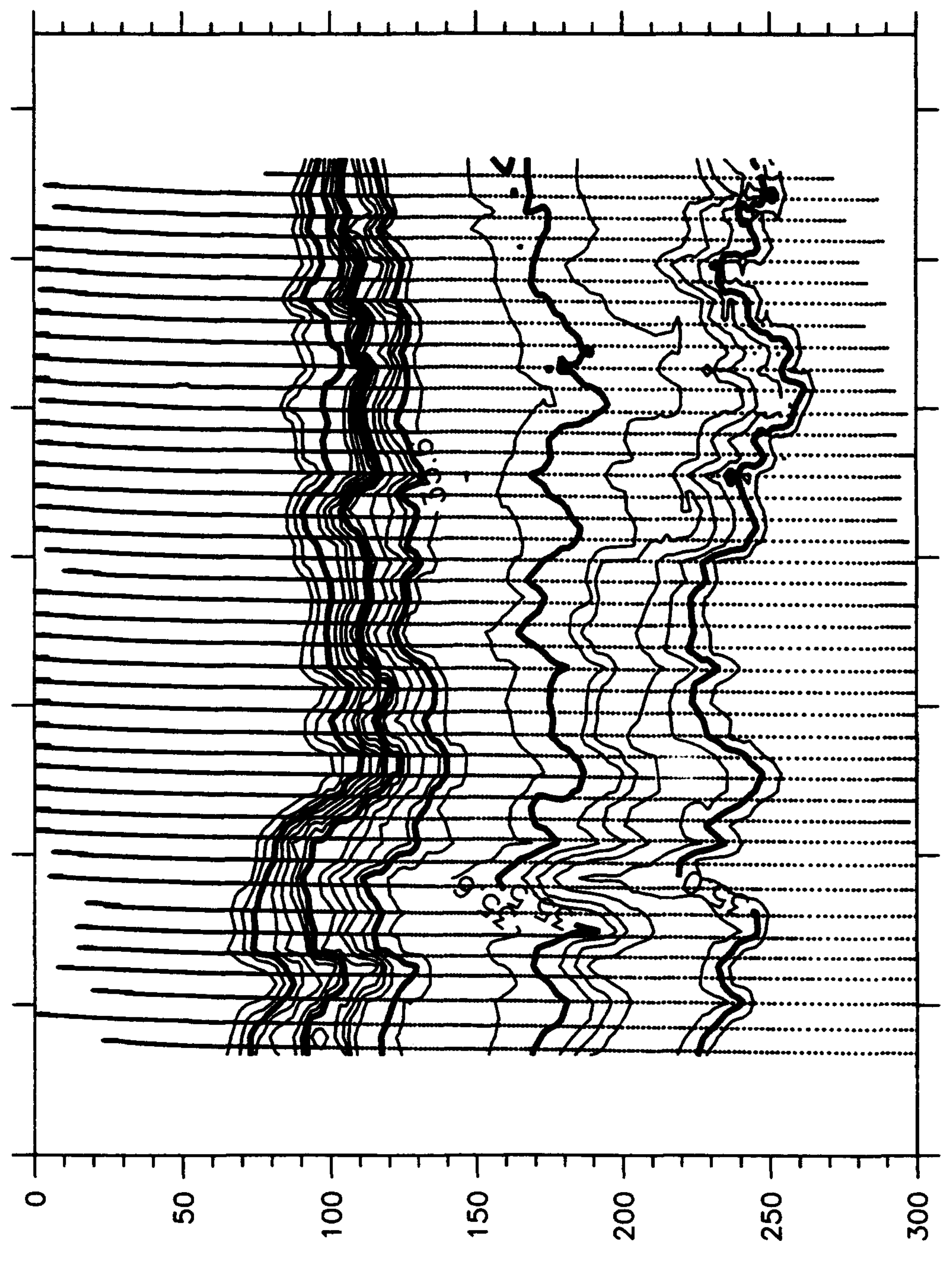
S(psu), S2W, 6 February 1993



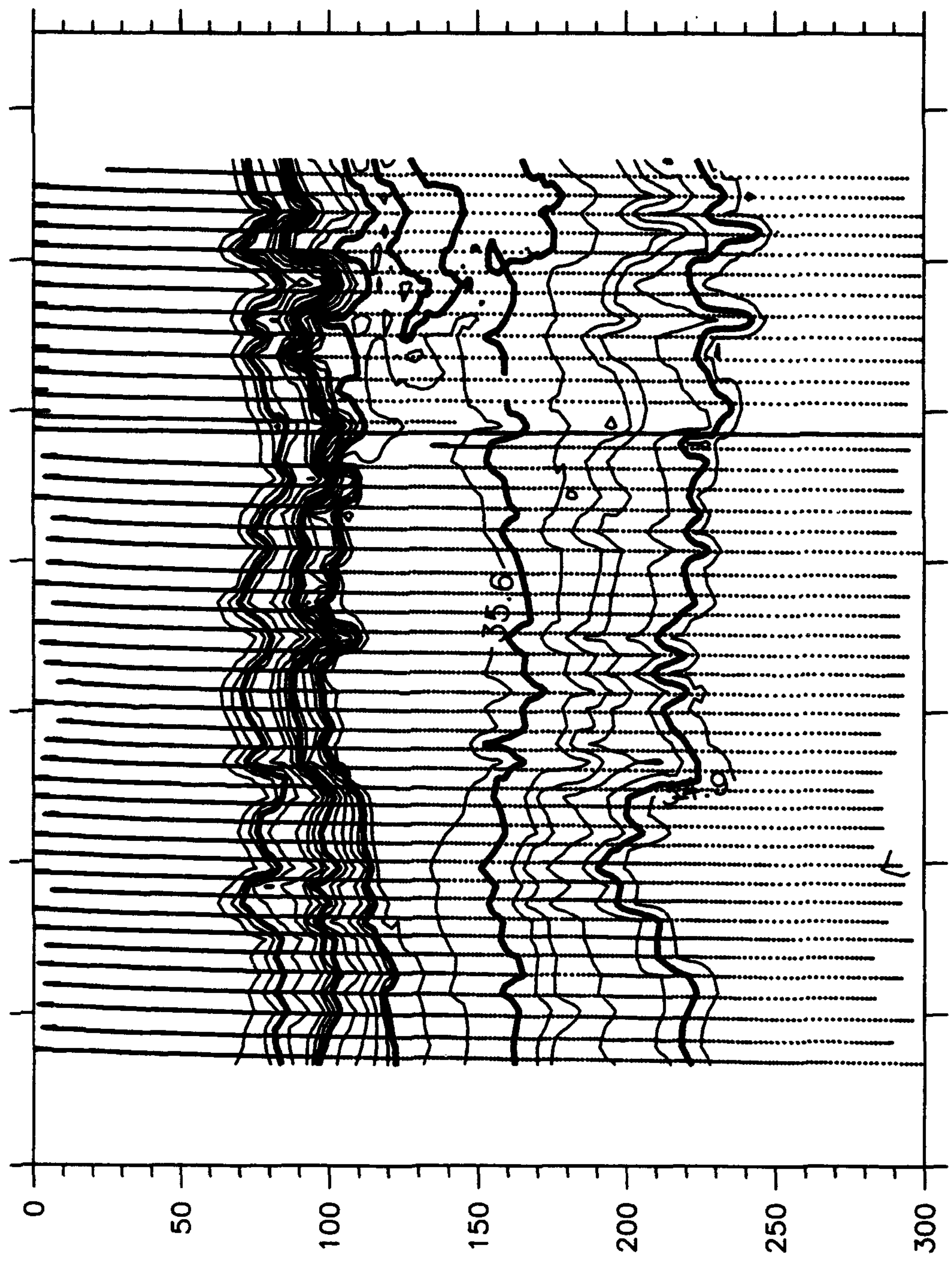
S(psu), S2W, 8 February 1993



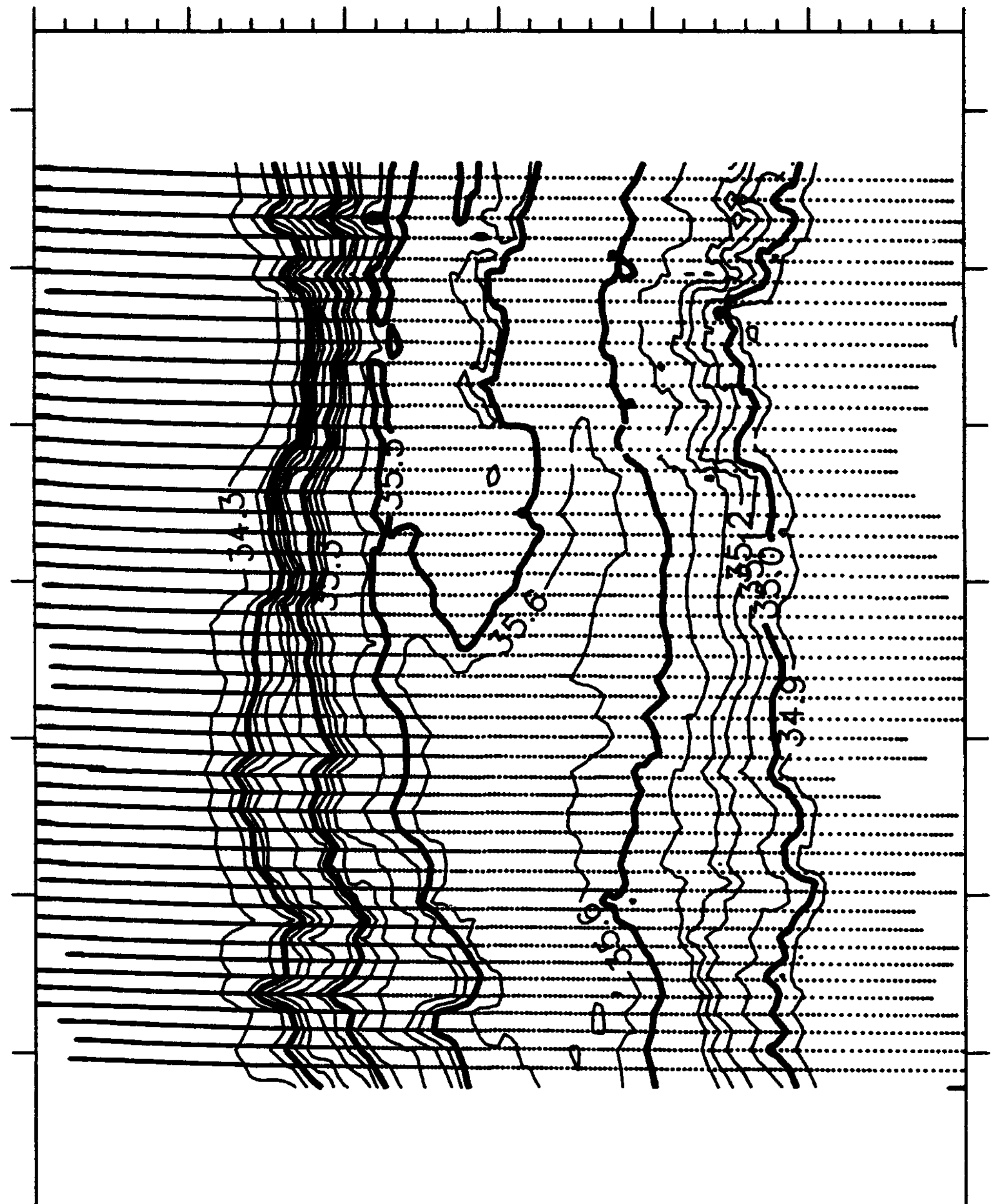
S(psu), S2W, 9 February 1993



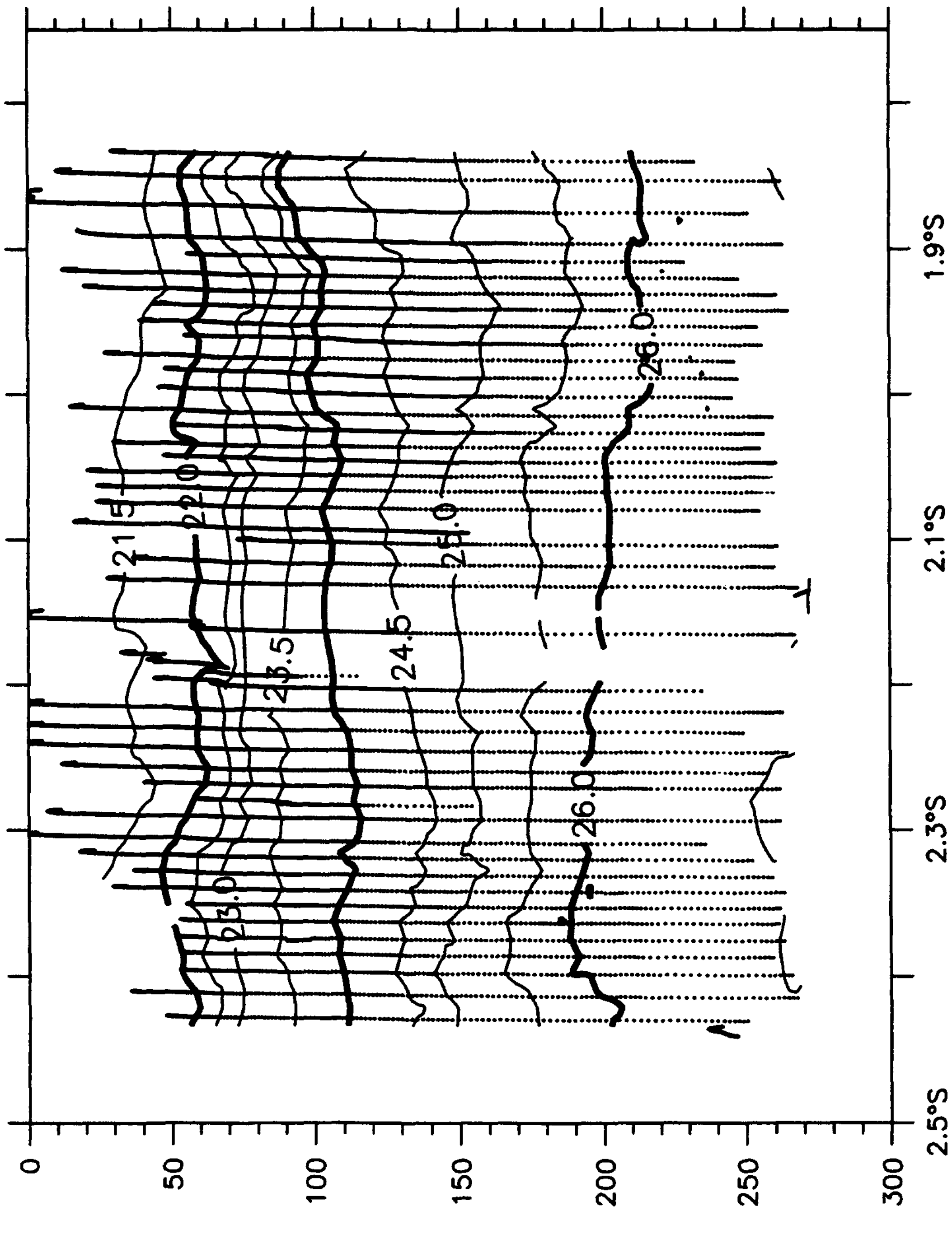
S(psu), S2W, 11 February 1993



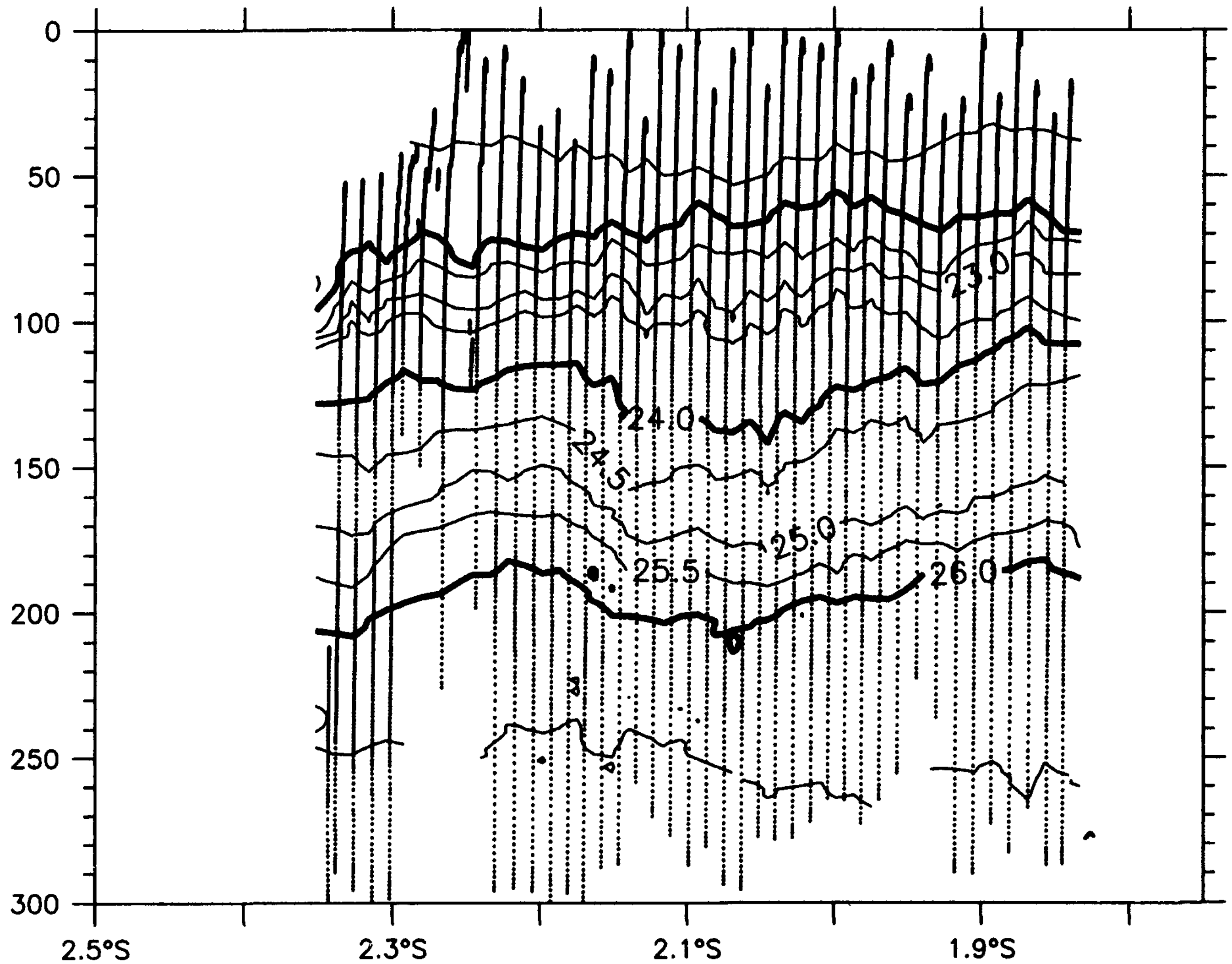
S(psu), S2W, 12–13 February 1993



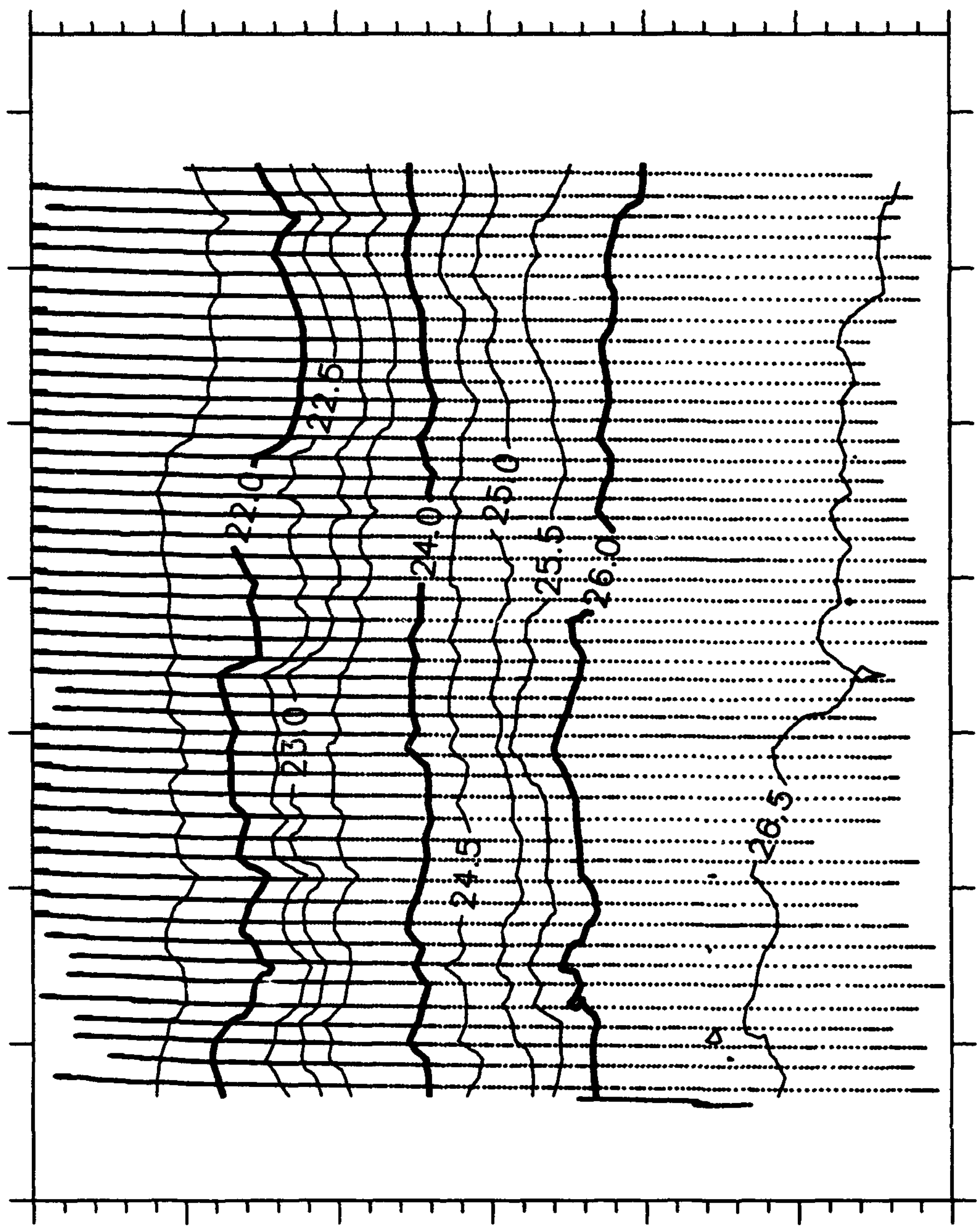
S(psu), S2W, 14 February 1993



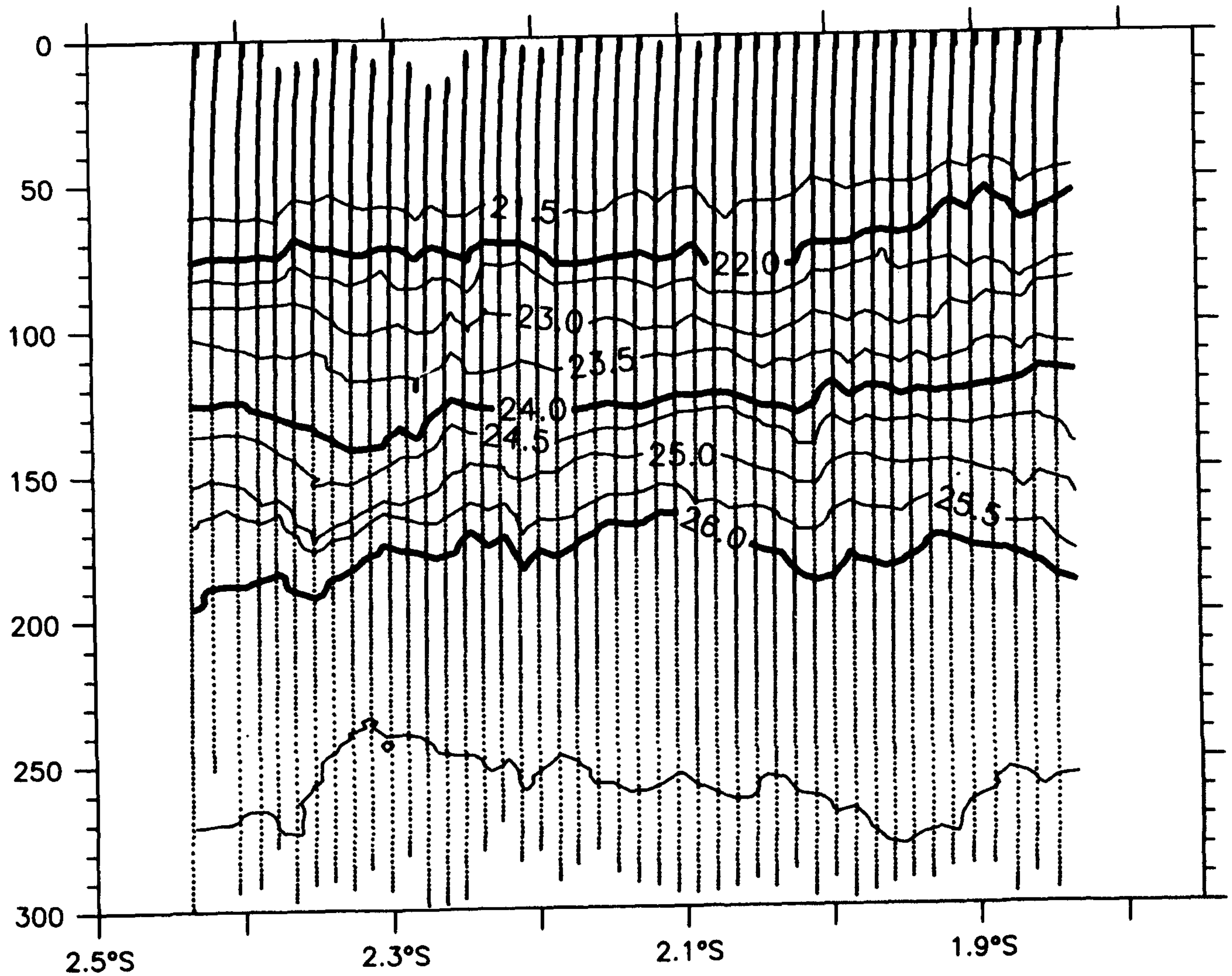
Sigma–t, S2W, 27 January 1993



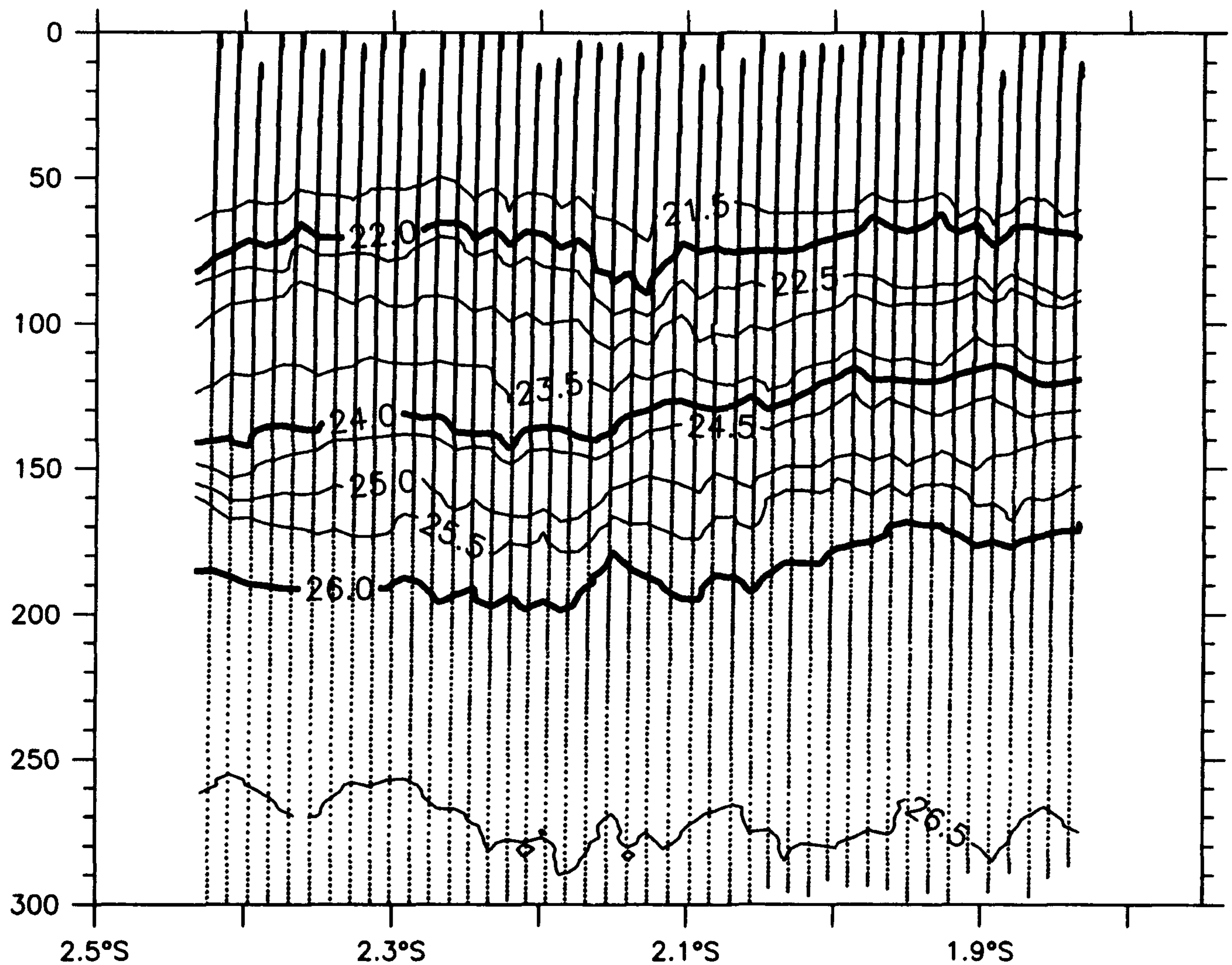
Sigma−t, S2W, 29 January 1993



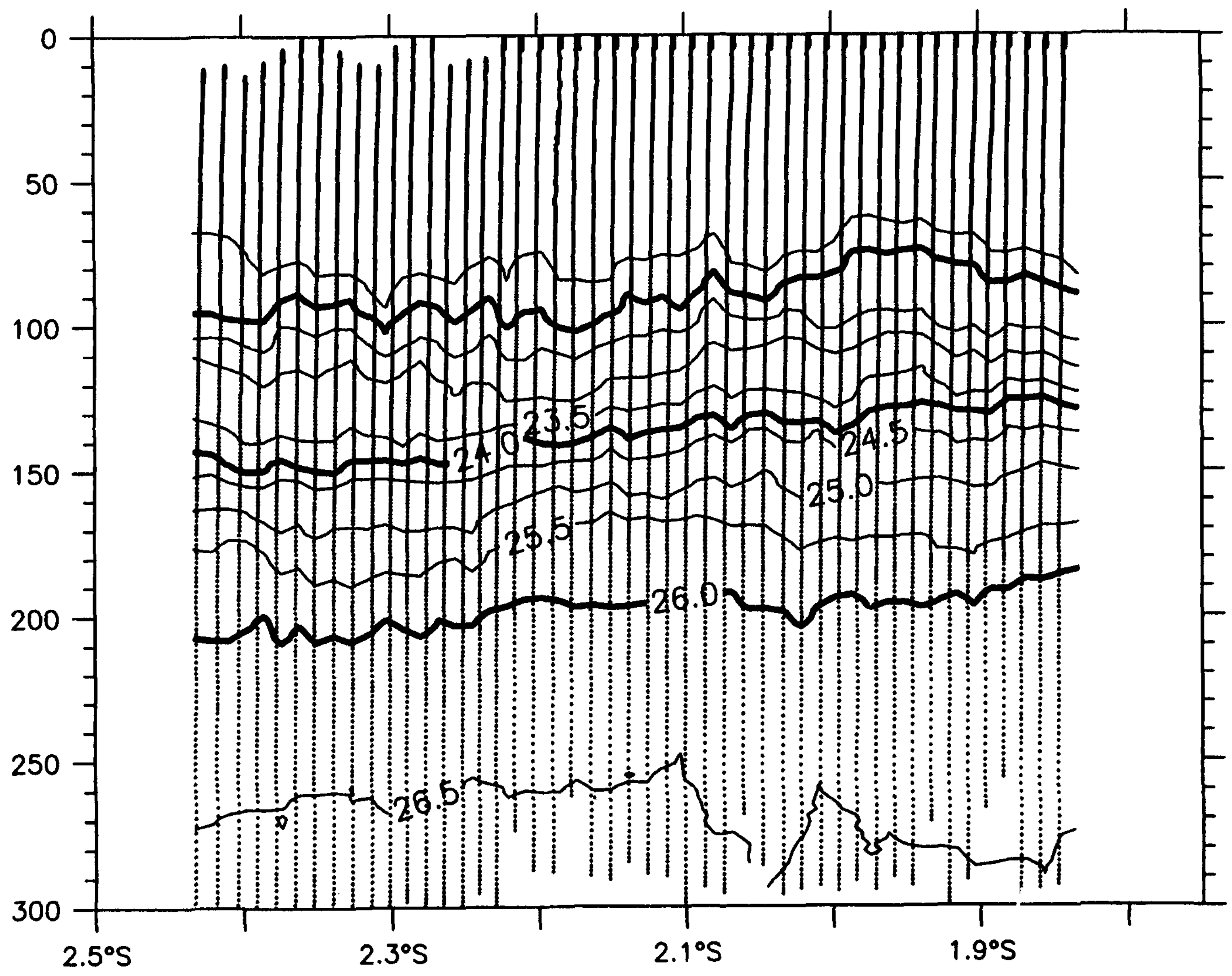
Sigma–t, S2W, 30 January 1993



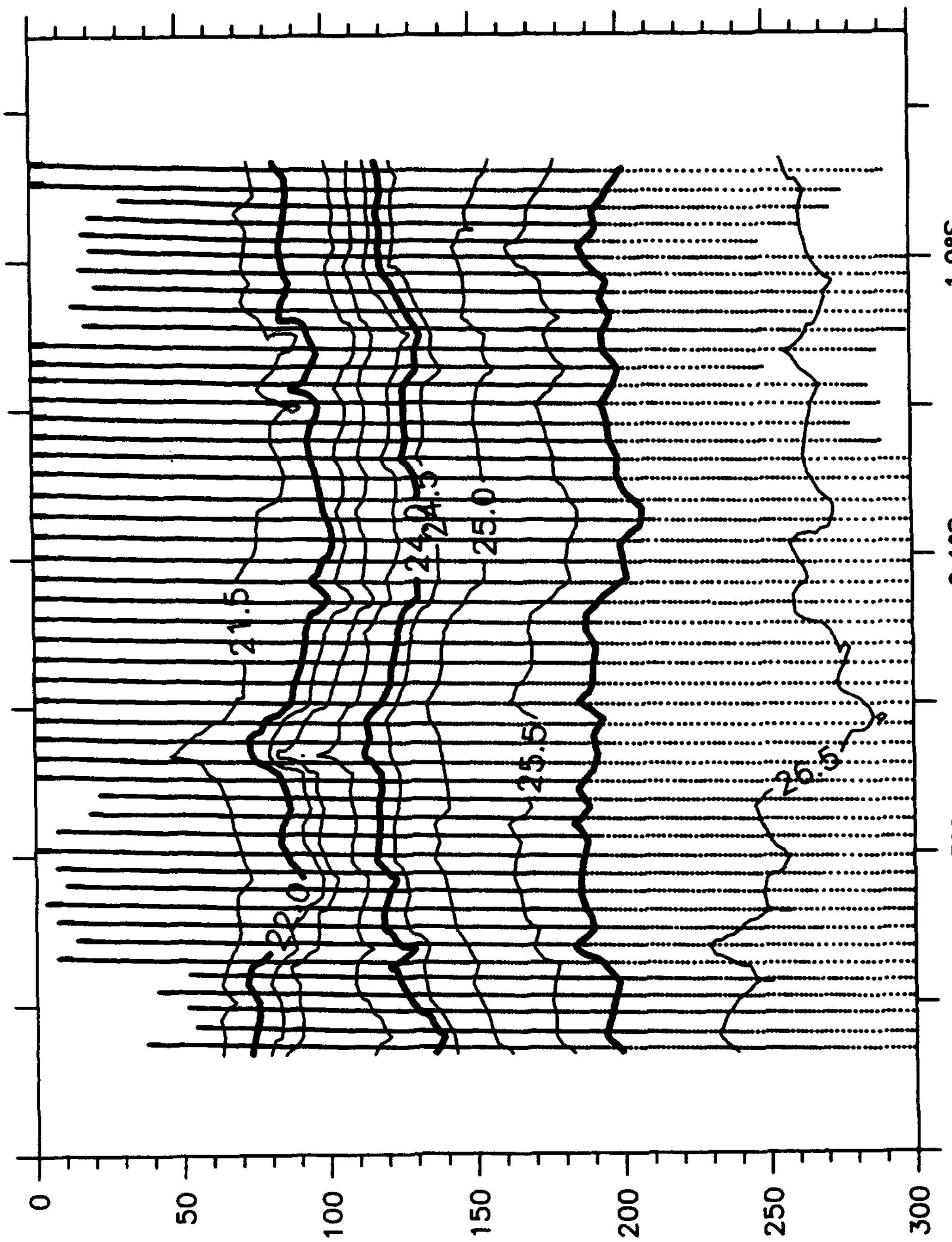
Sigma–t, S2W, 1 February 1993



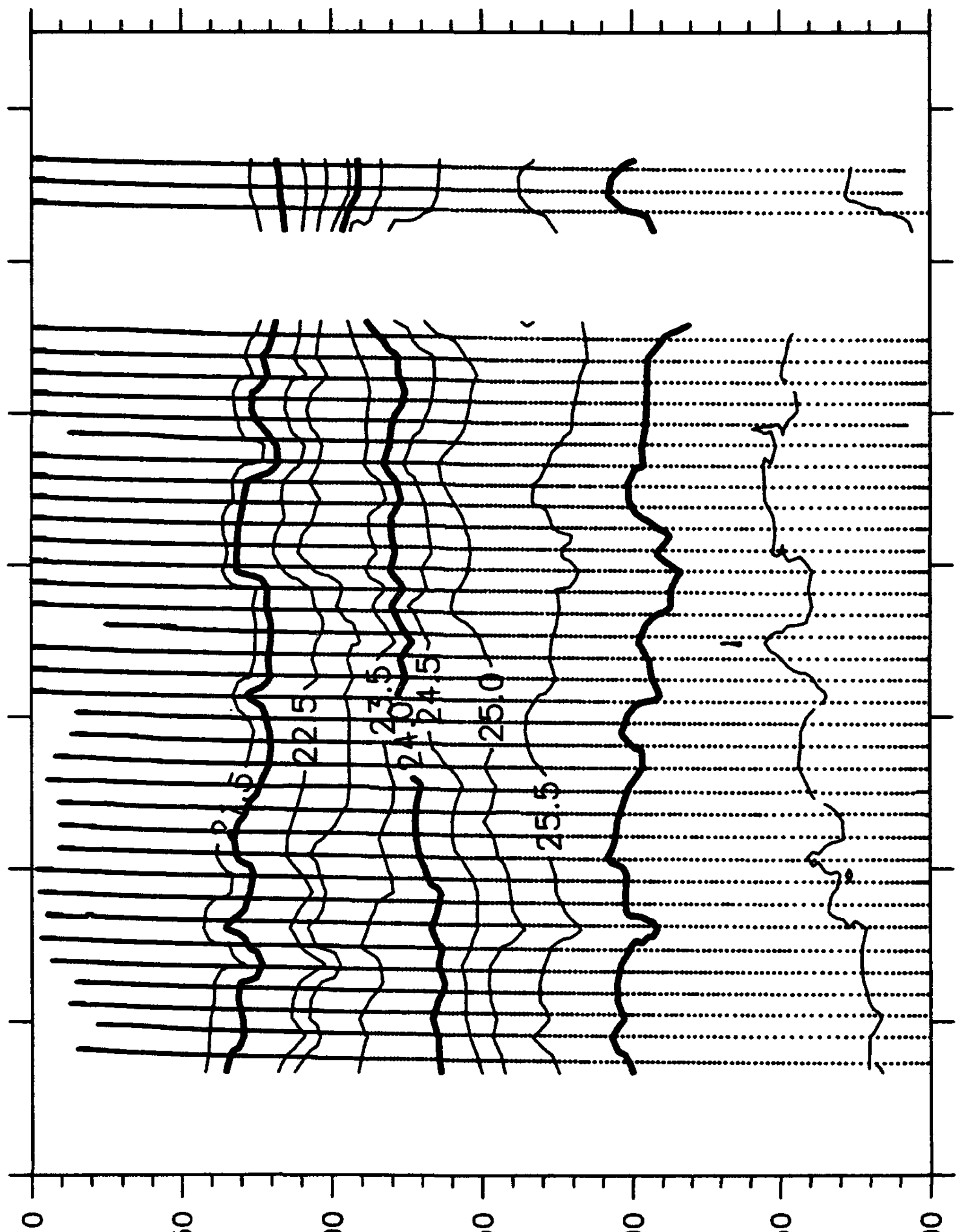
Sigma–t, S2W, 2 February 1993



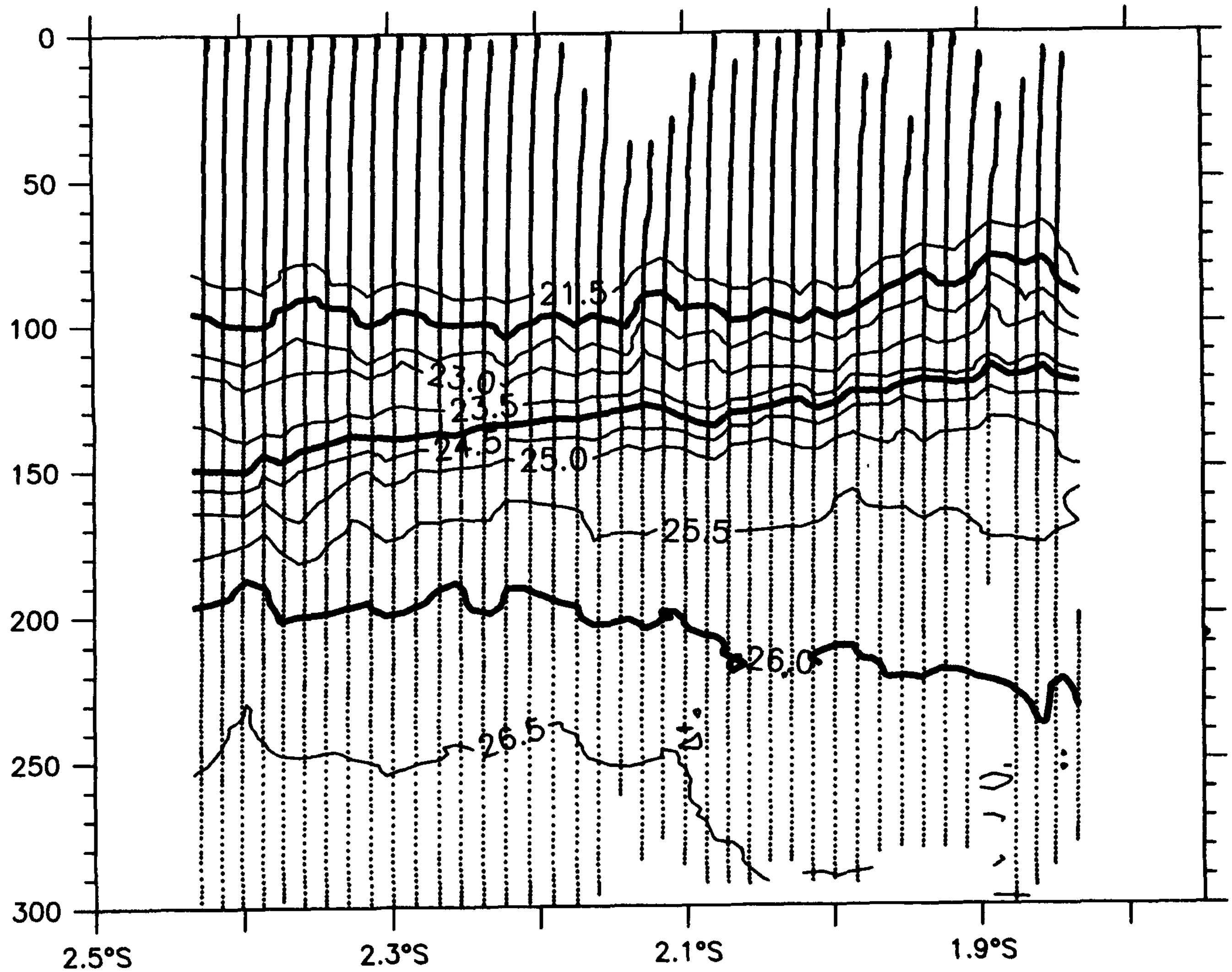
Sigma–t, S2W, 4 February 1993



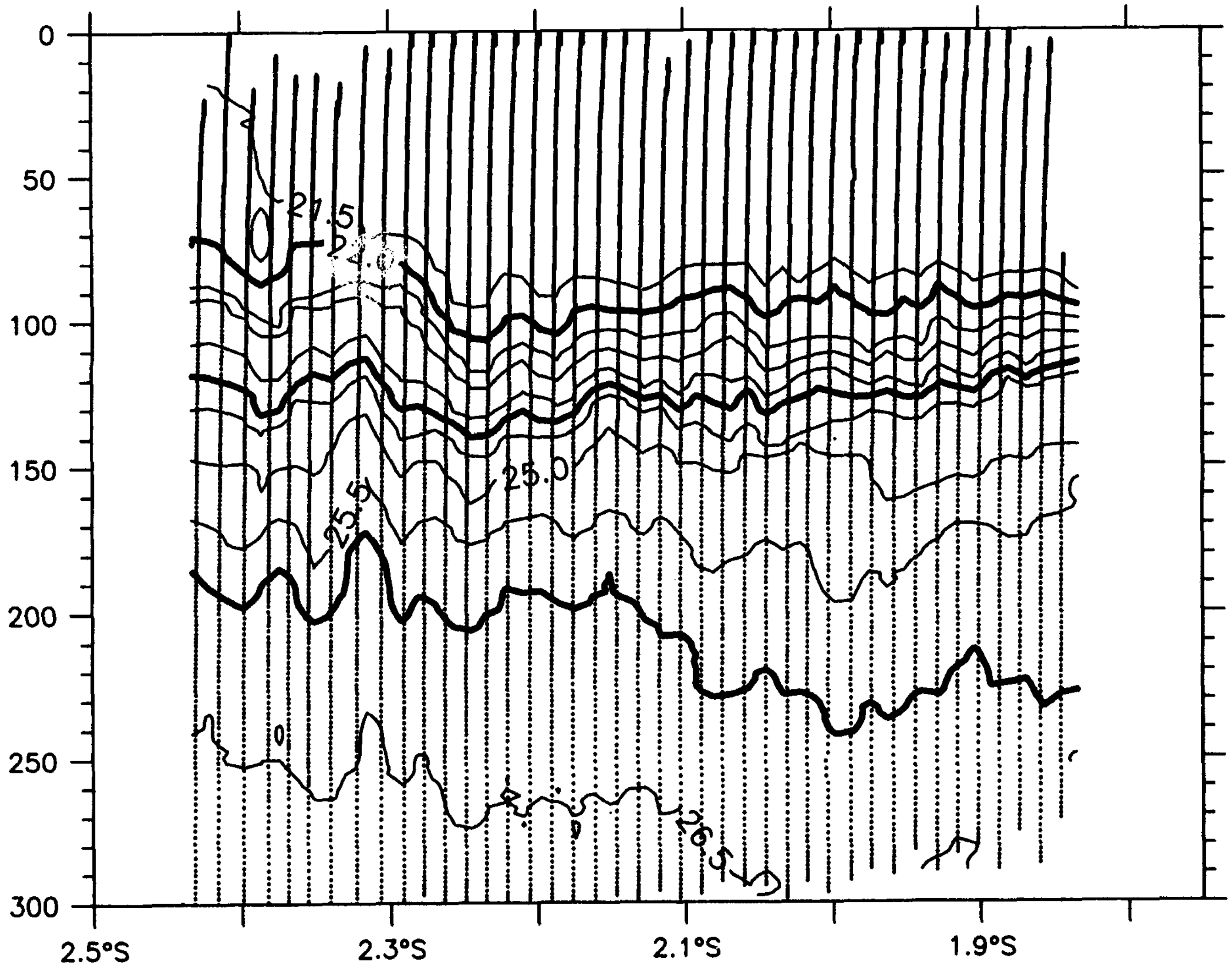
Sigma-t, S2W, 6 February 1993



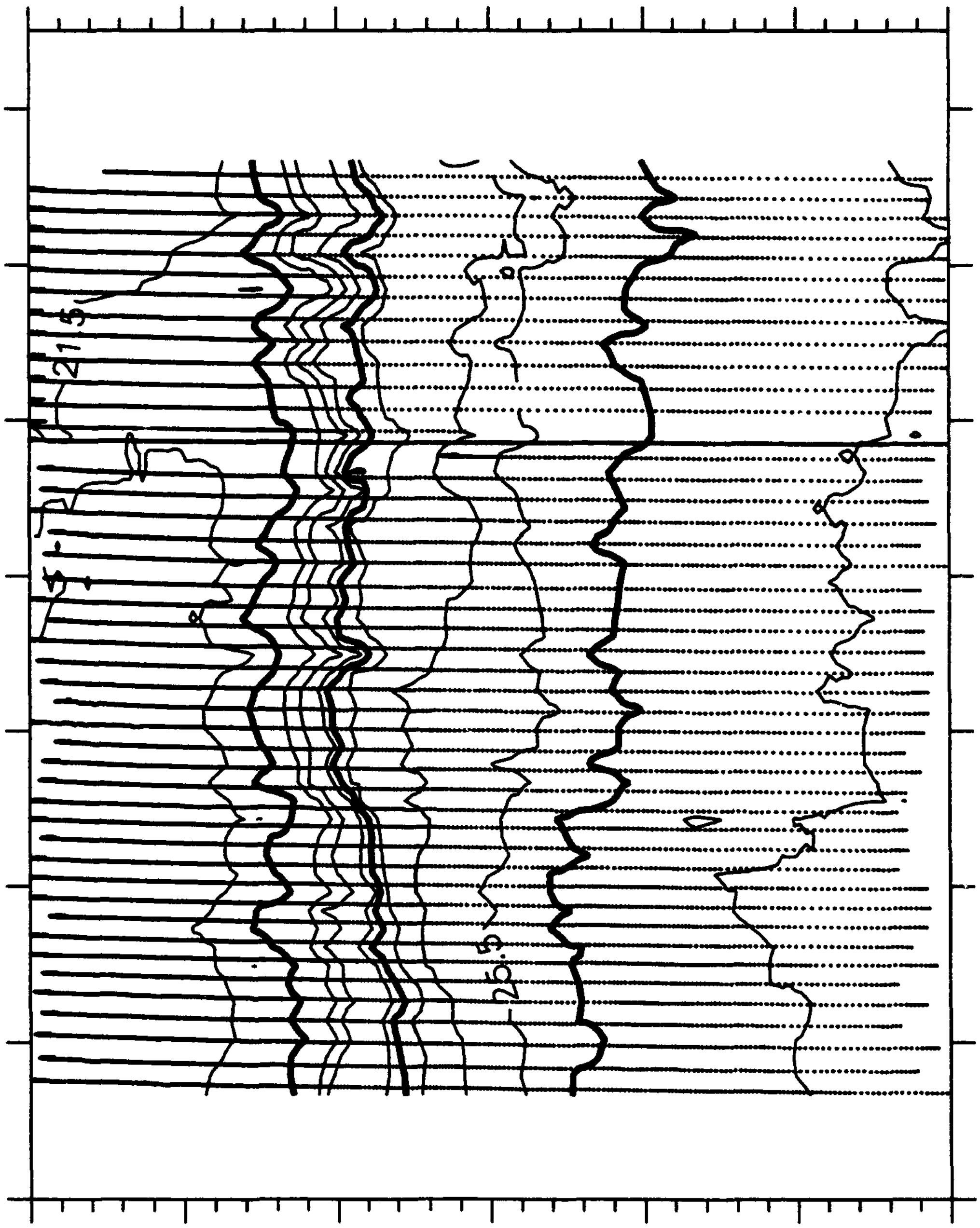
Sigma—t, S2W, 8 February 1993



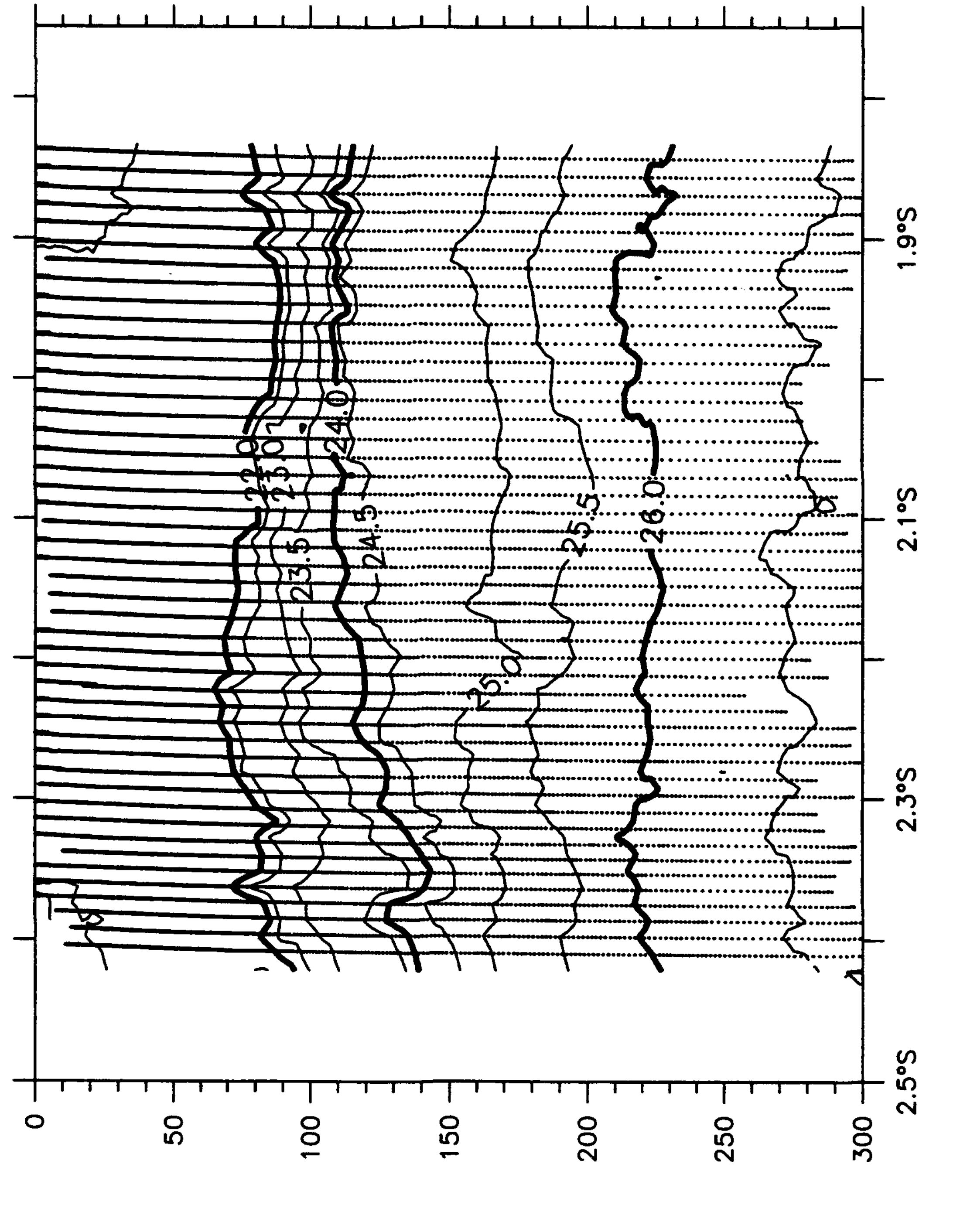
Sigma–t, S2W, 9 February 1993



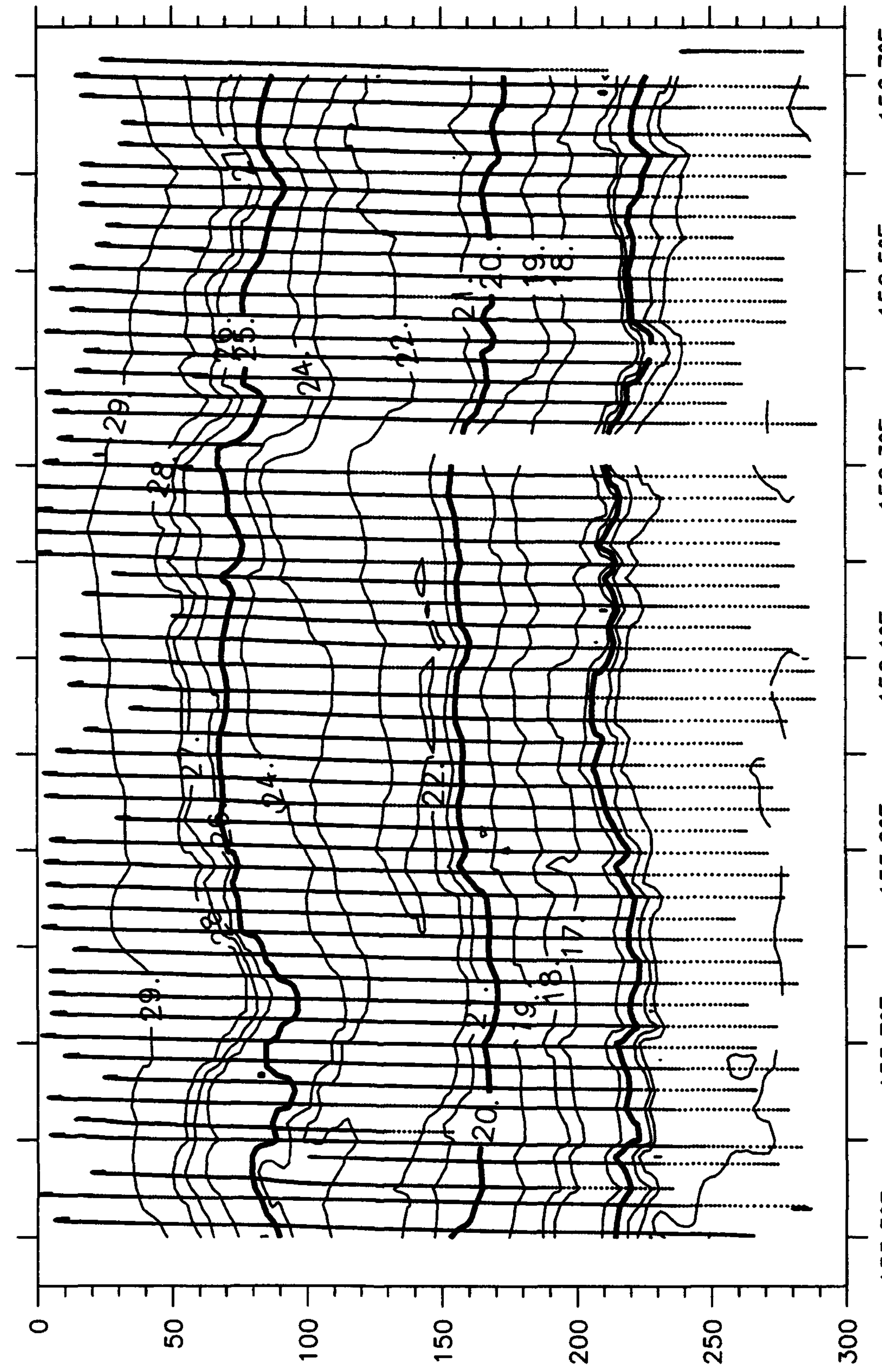
Sigma–t, S2W, 11 February 1993



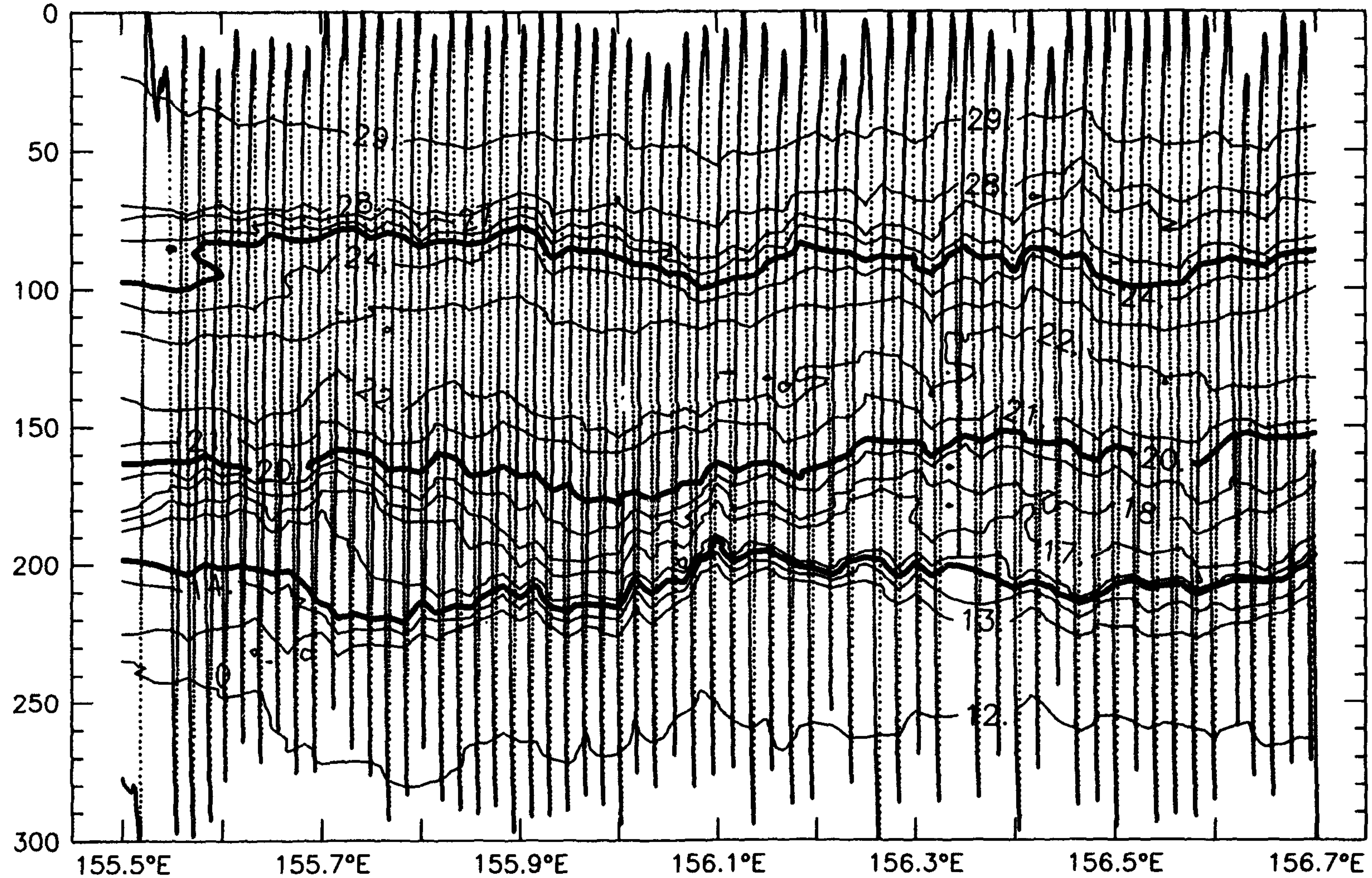
Sigma–t, S2W, 12–13 February 1993



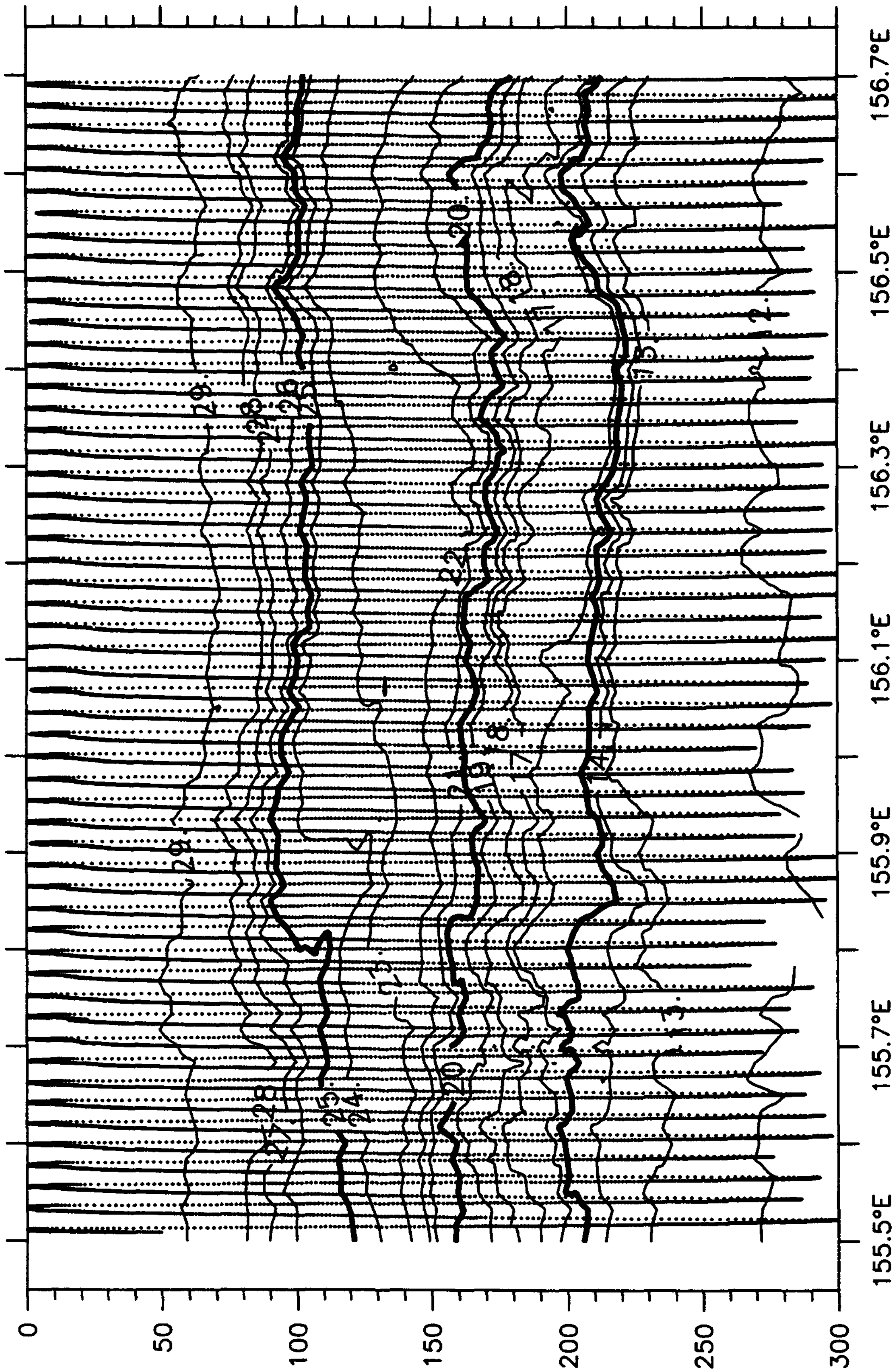
Sigma–t, S2W, 14 February 1993



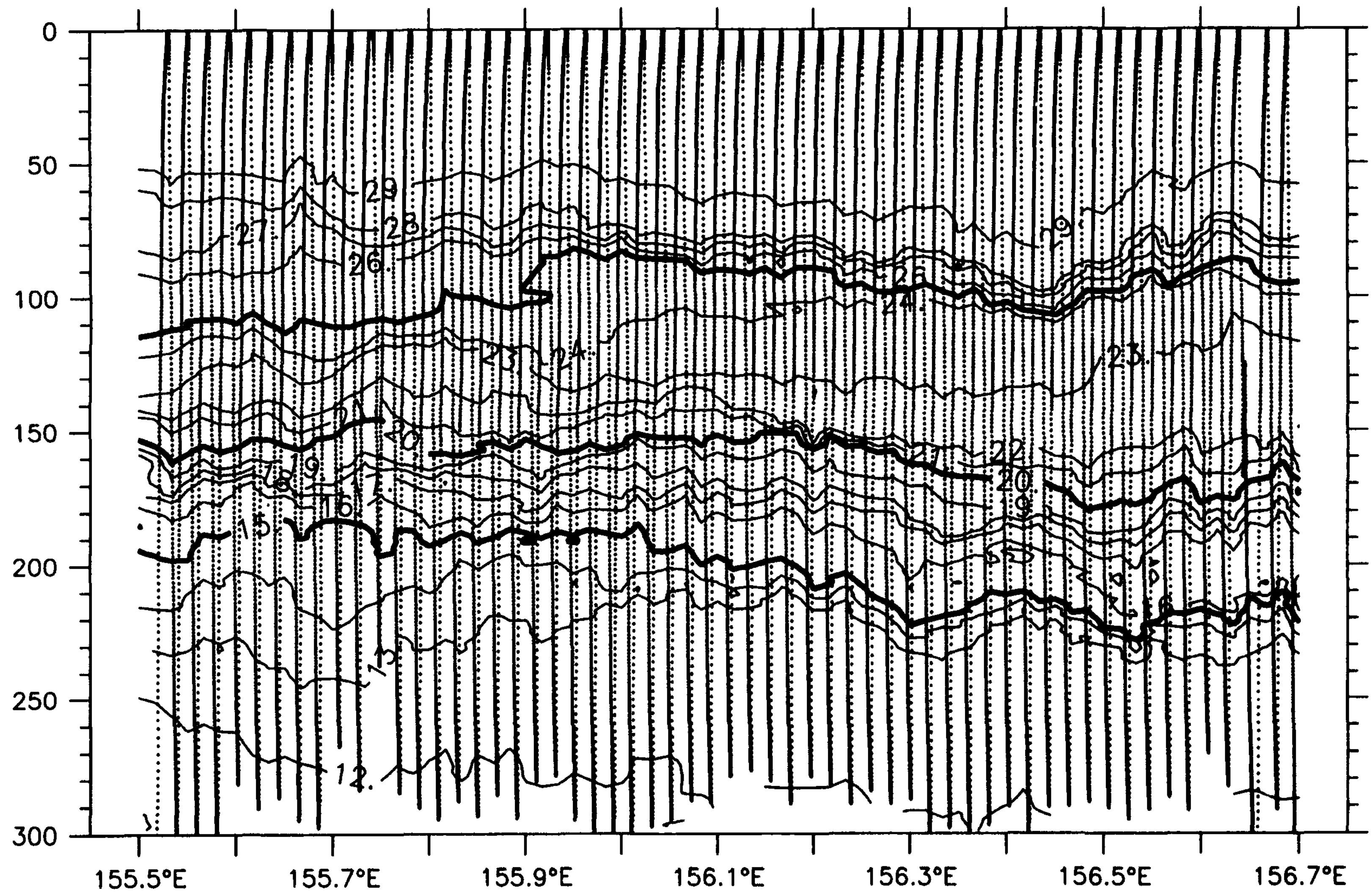
T(°C), W2E, 28 January 1993



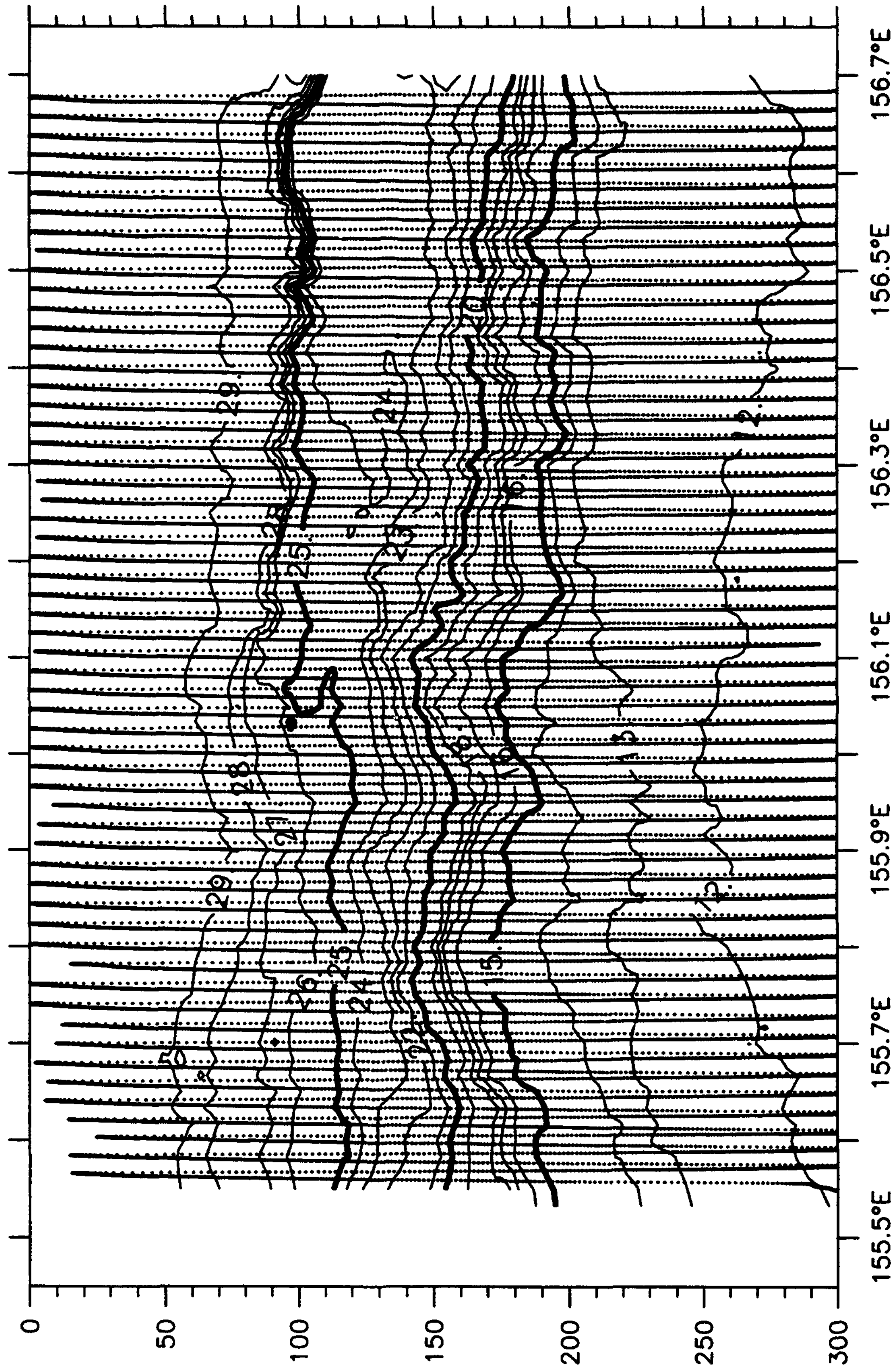
T(°C), W2E, 29 January 1993



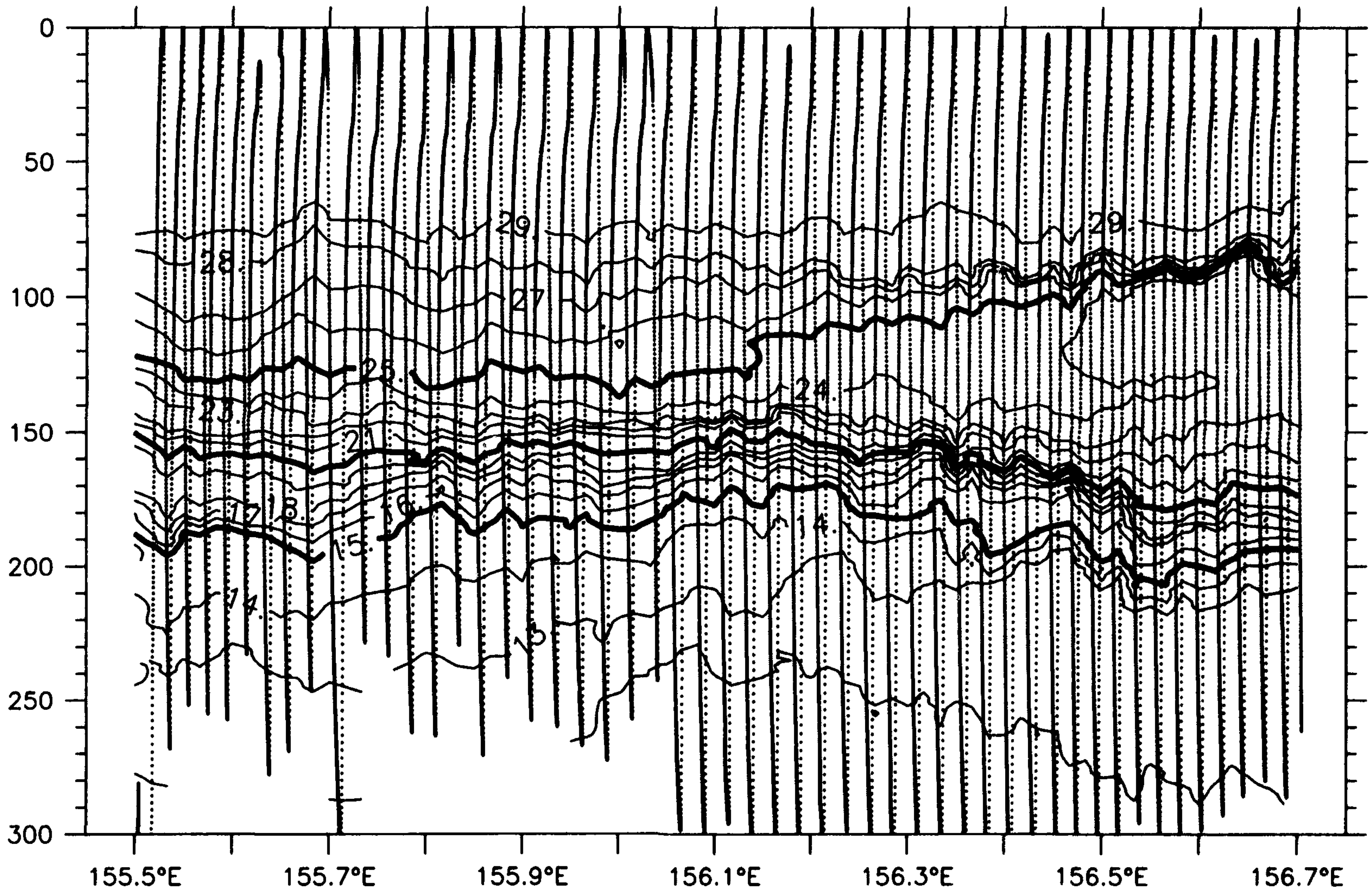
T(°C), W2E, 31 January 1993



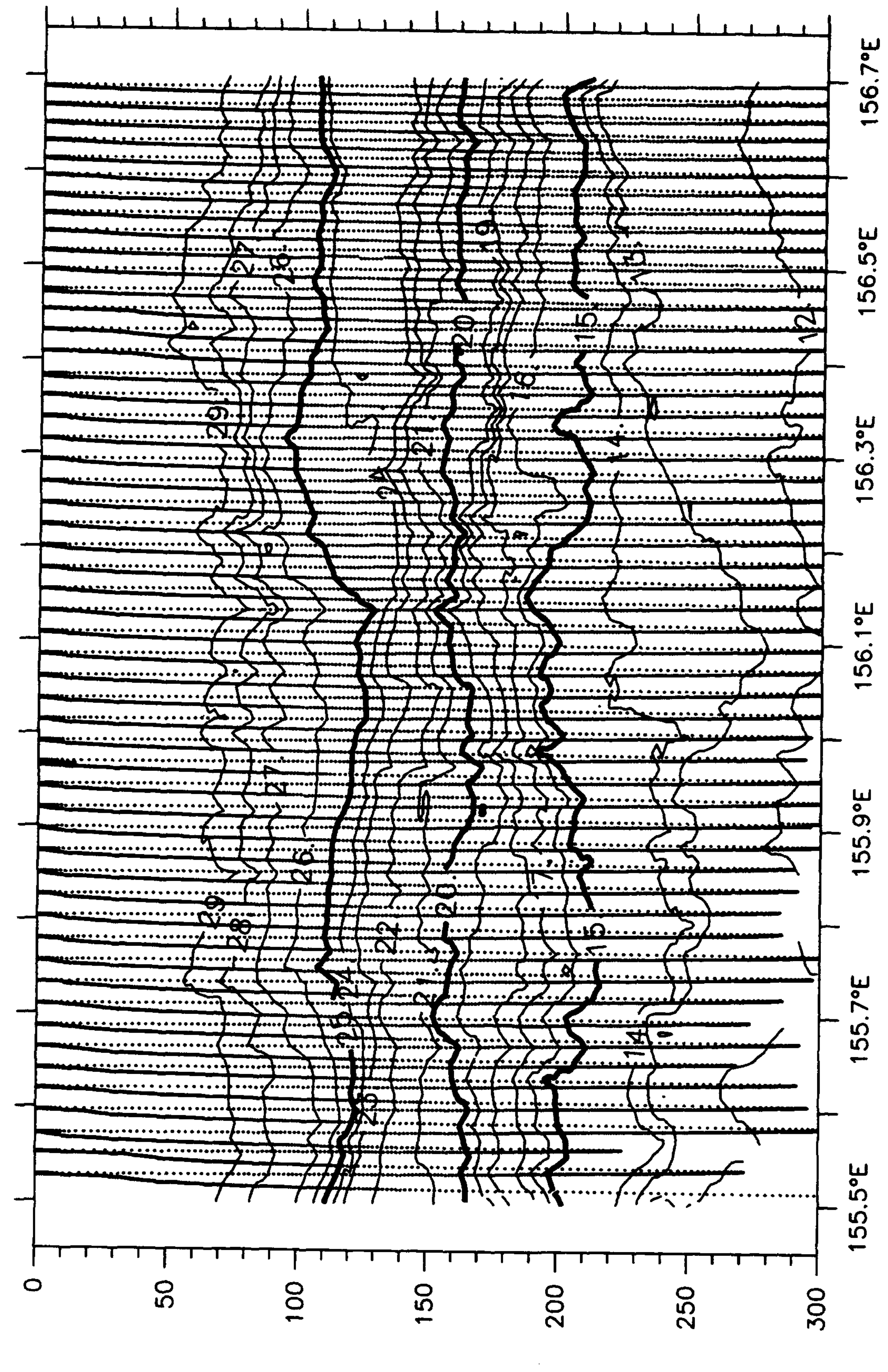
T(°C), W2E, 1 February 1993



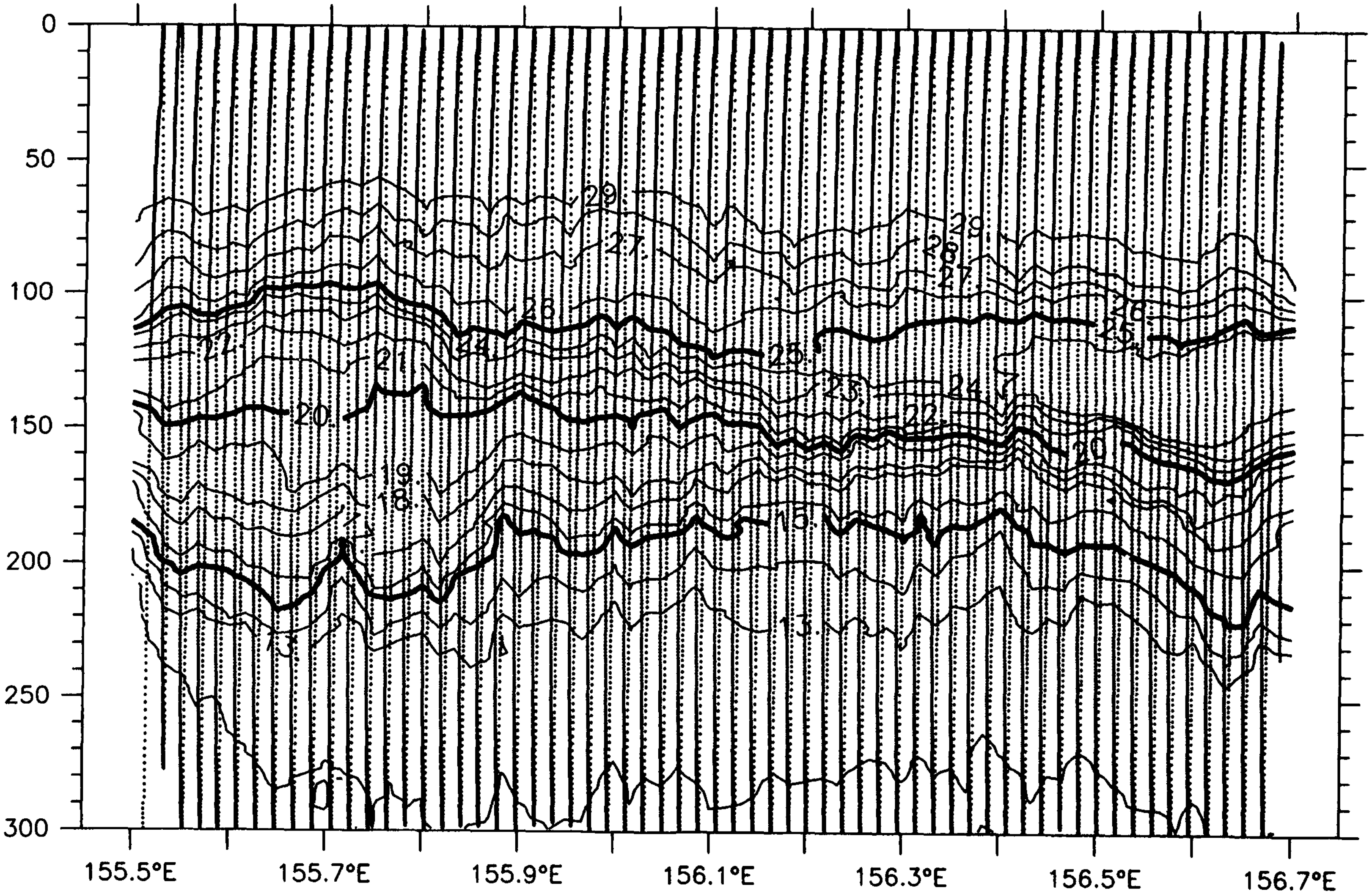
T(°C), W2E, 3 February 1993



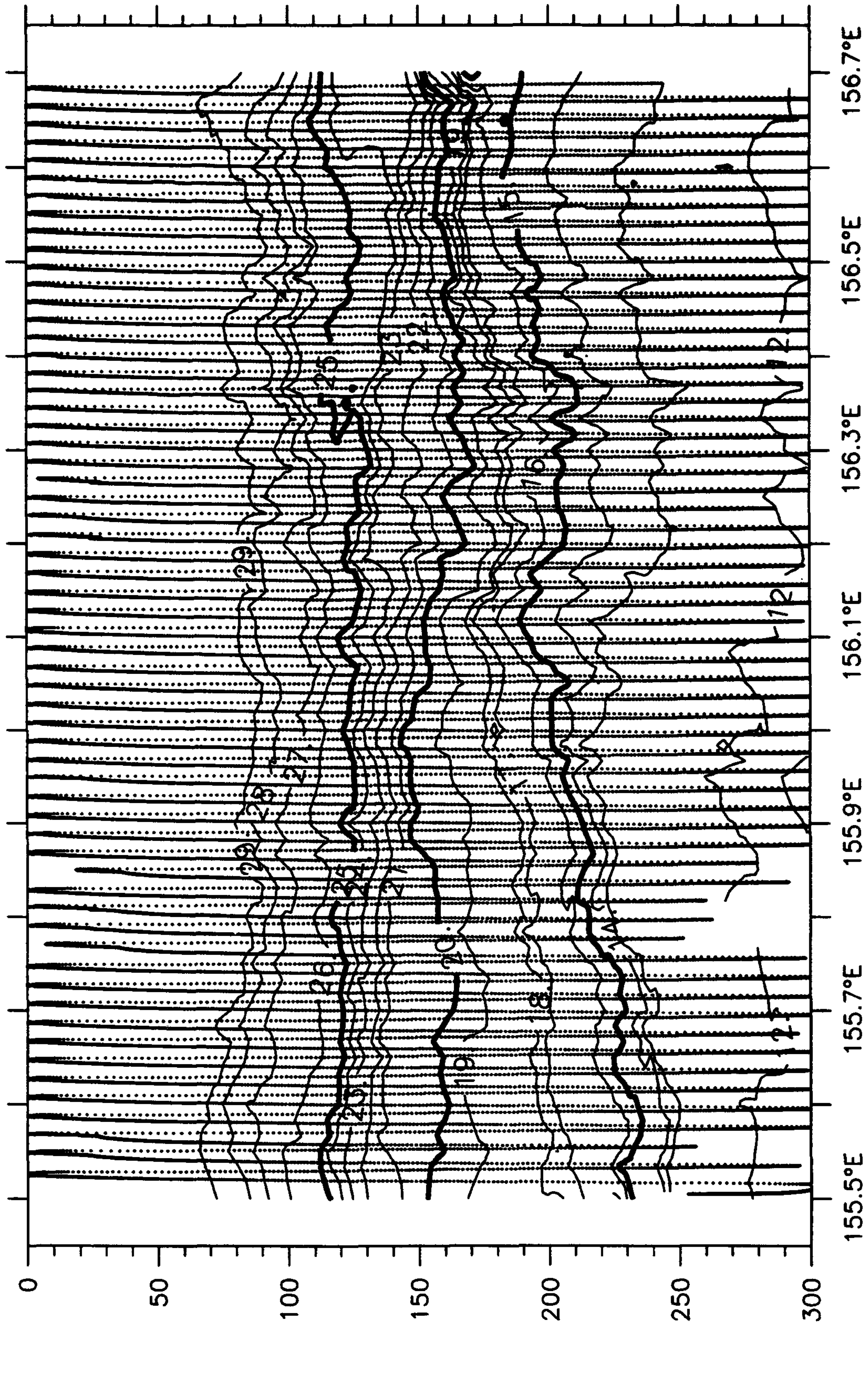
T(°C), W2E, 04 February 1993



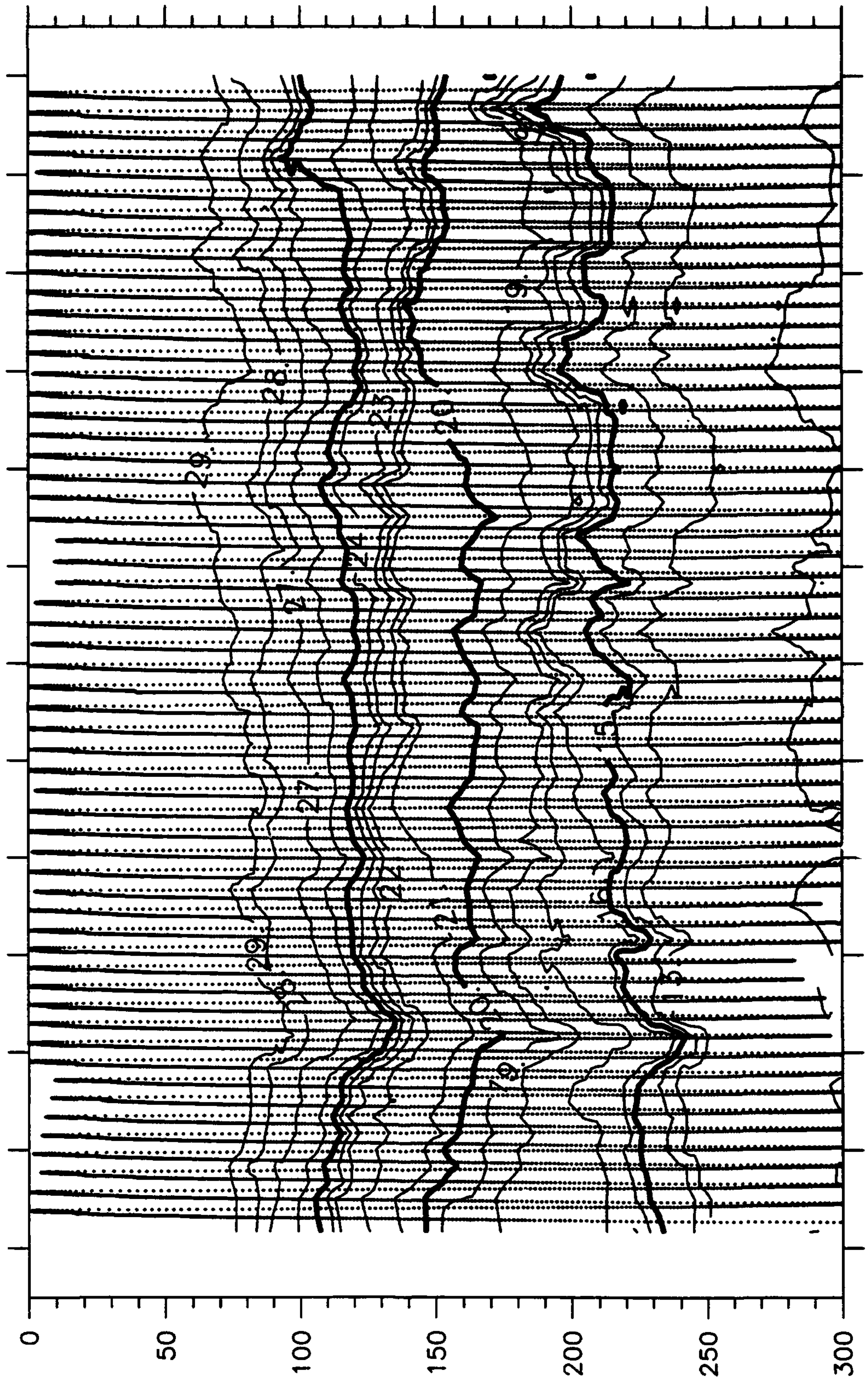
T(°C), W2E, 06 February 1993



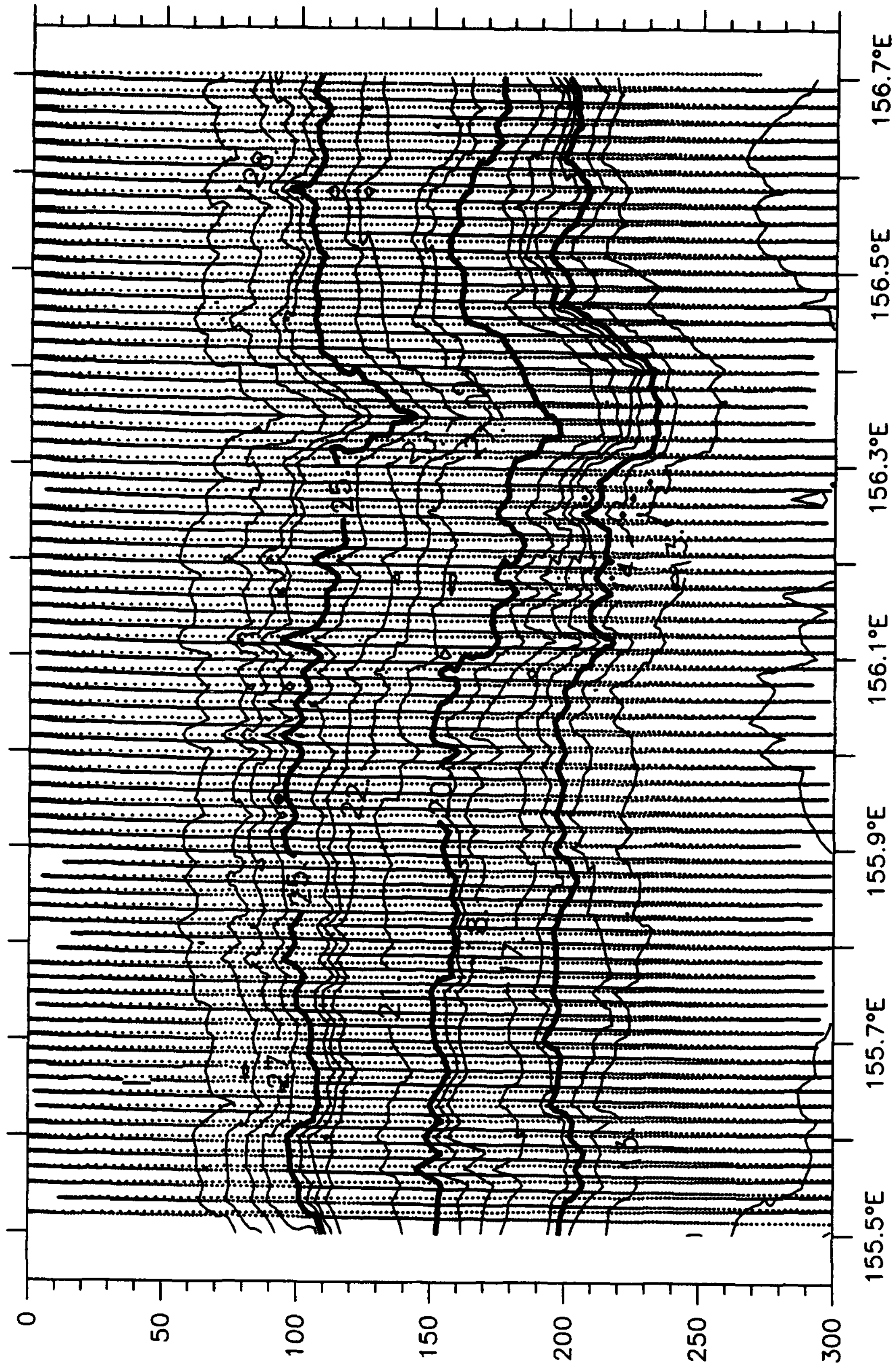
T(°C), W2E, 08 February 1993



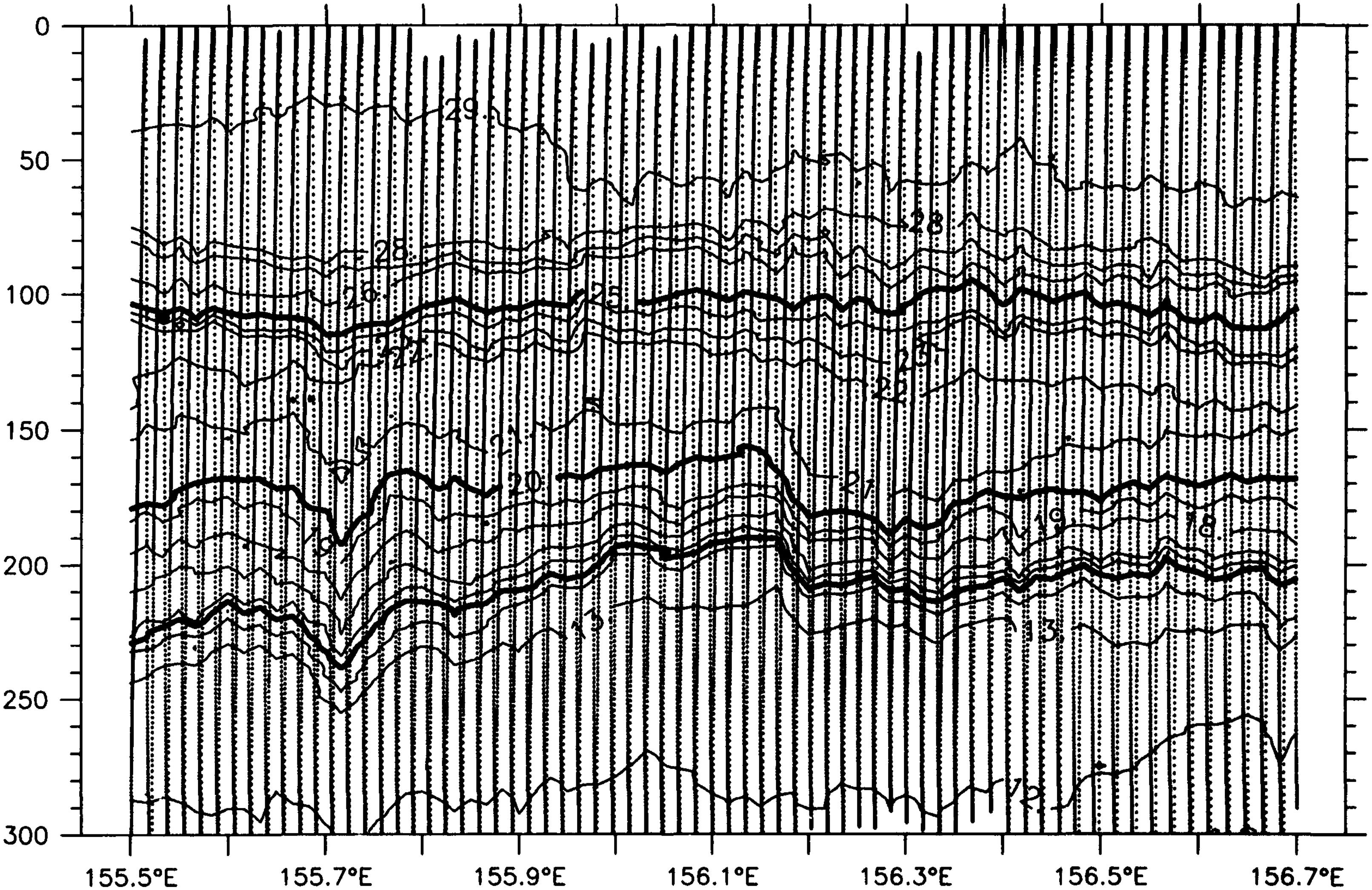
T(°C), W2E, 10 February 1993



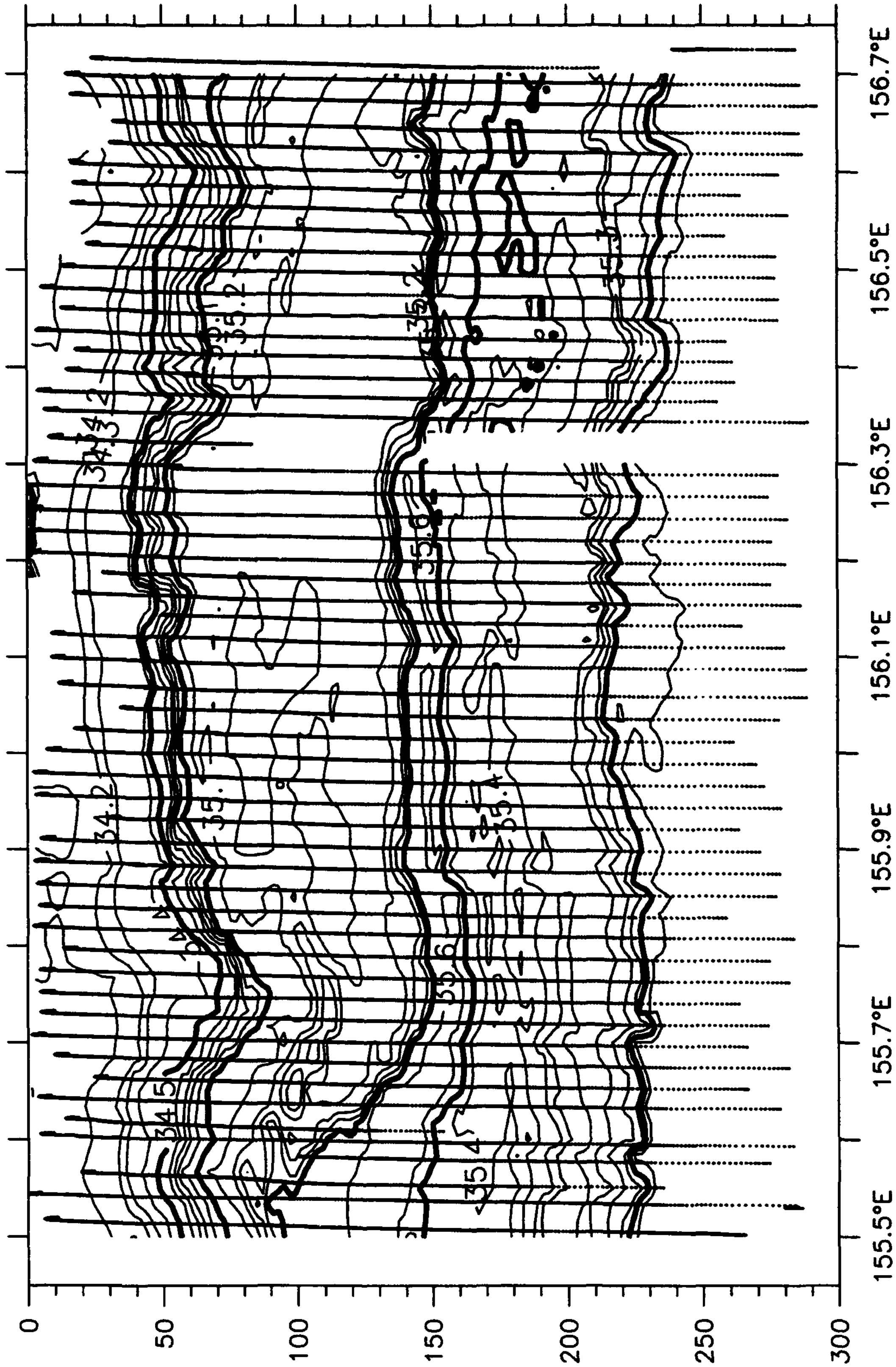
T(°C), W2E, 11 February 1993



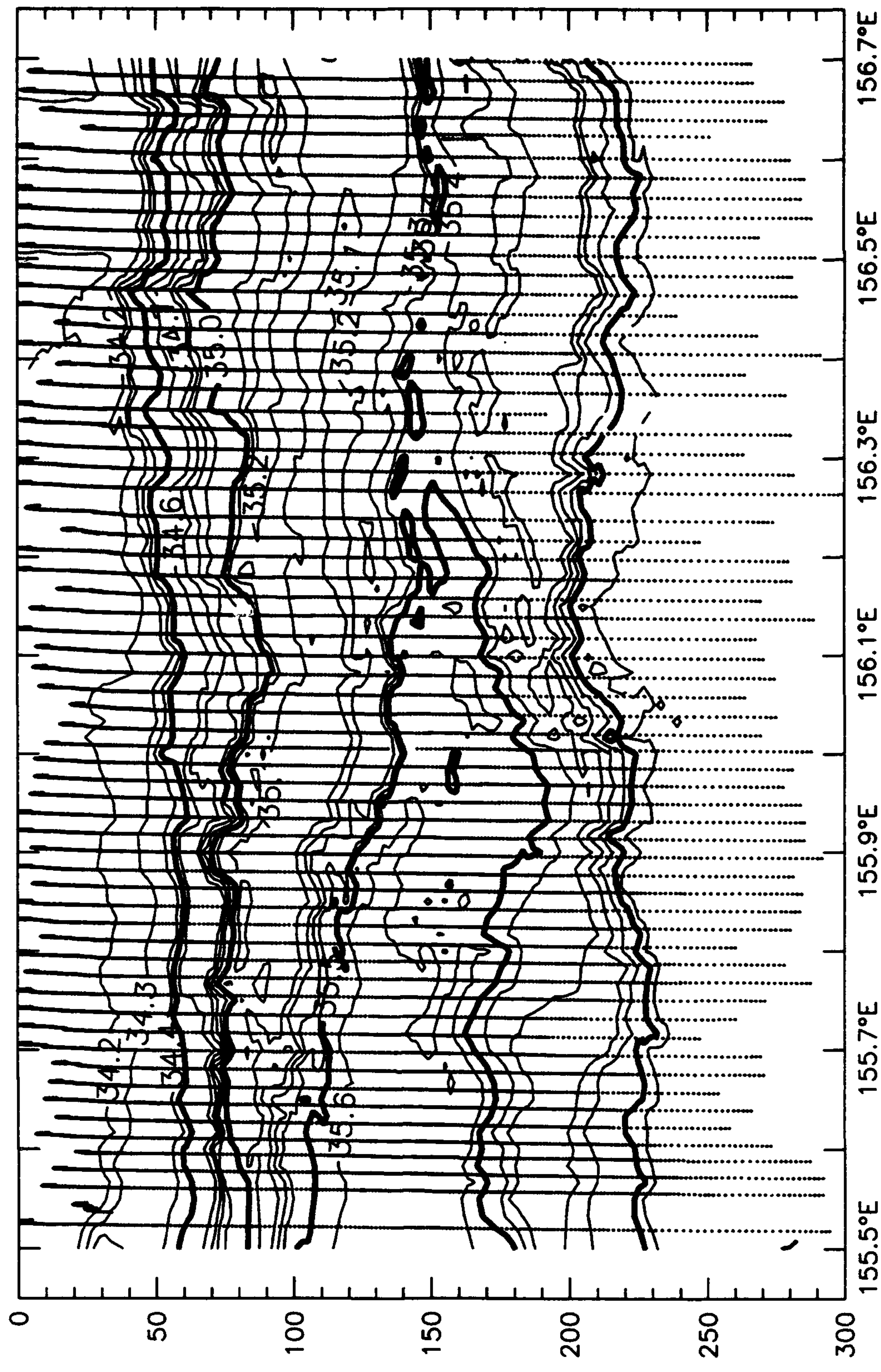
T(°C), W2E, 13 February 1993



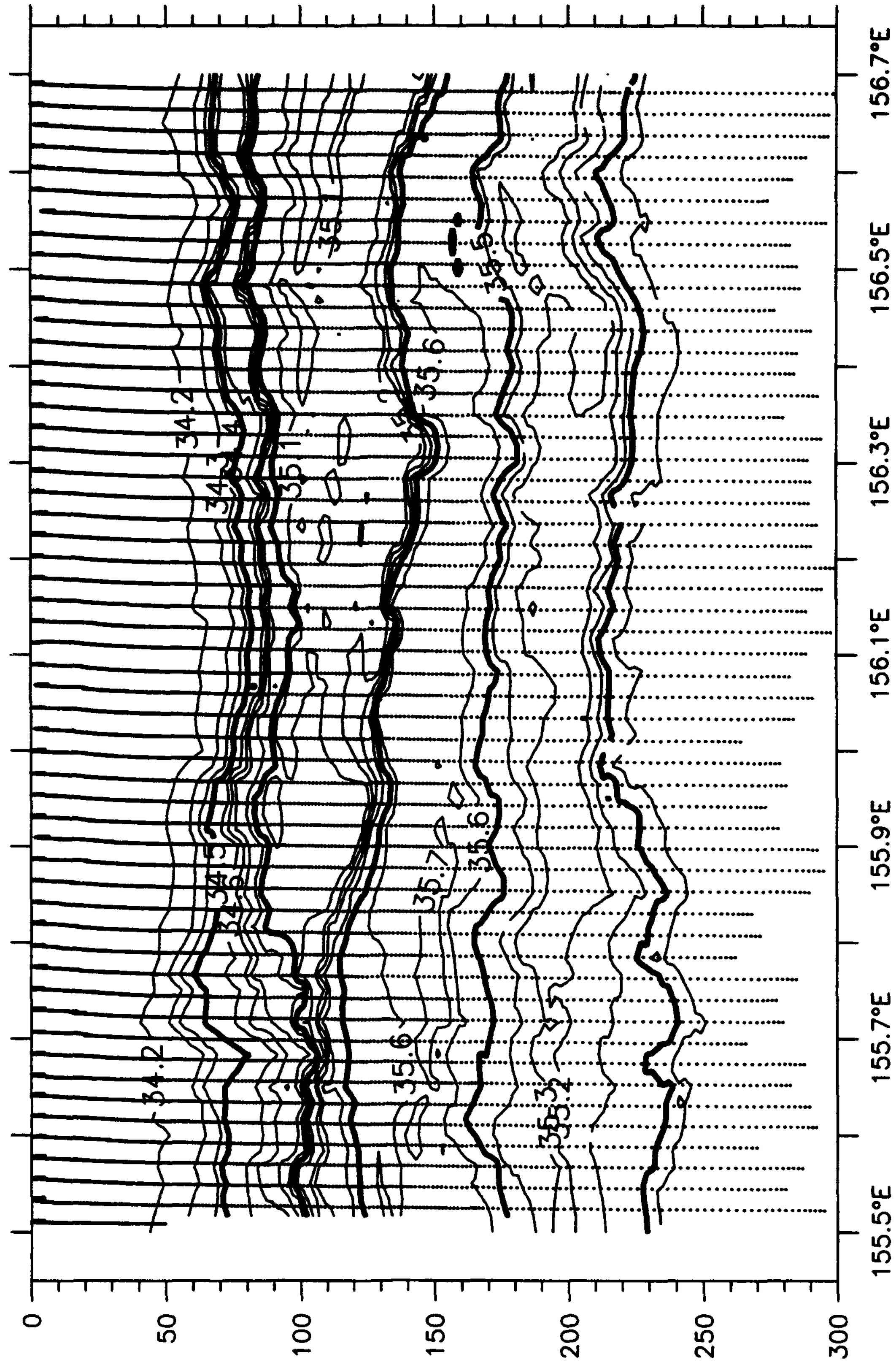
T(°C), W2E, 14 February 1993



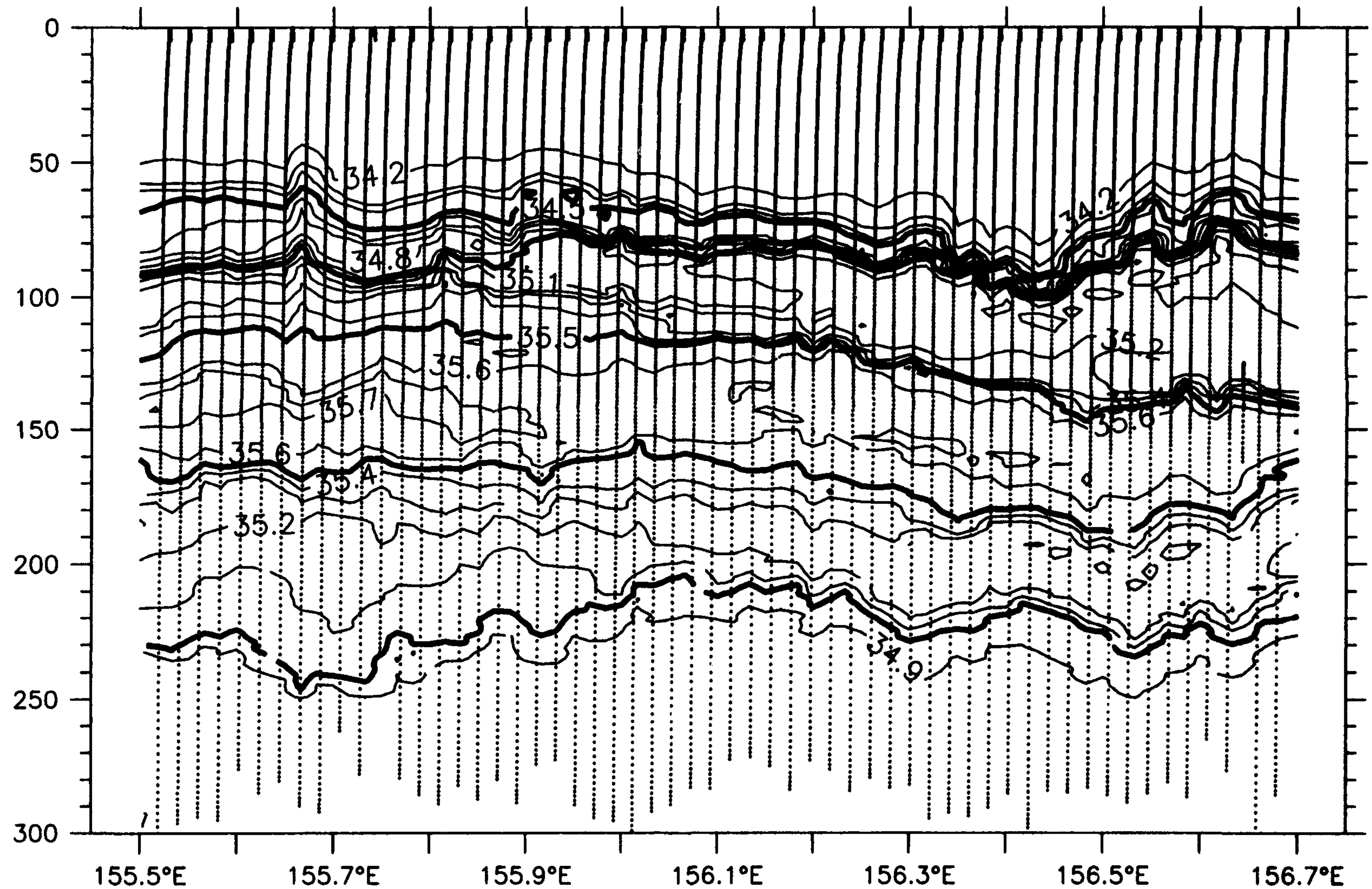
S(psu), W2E, 28 January 1993



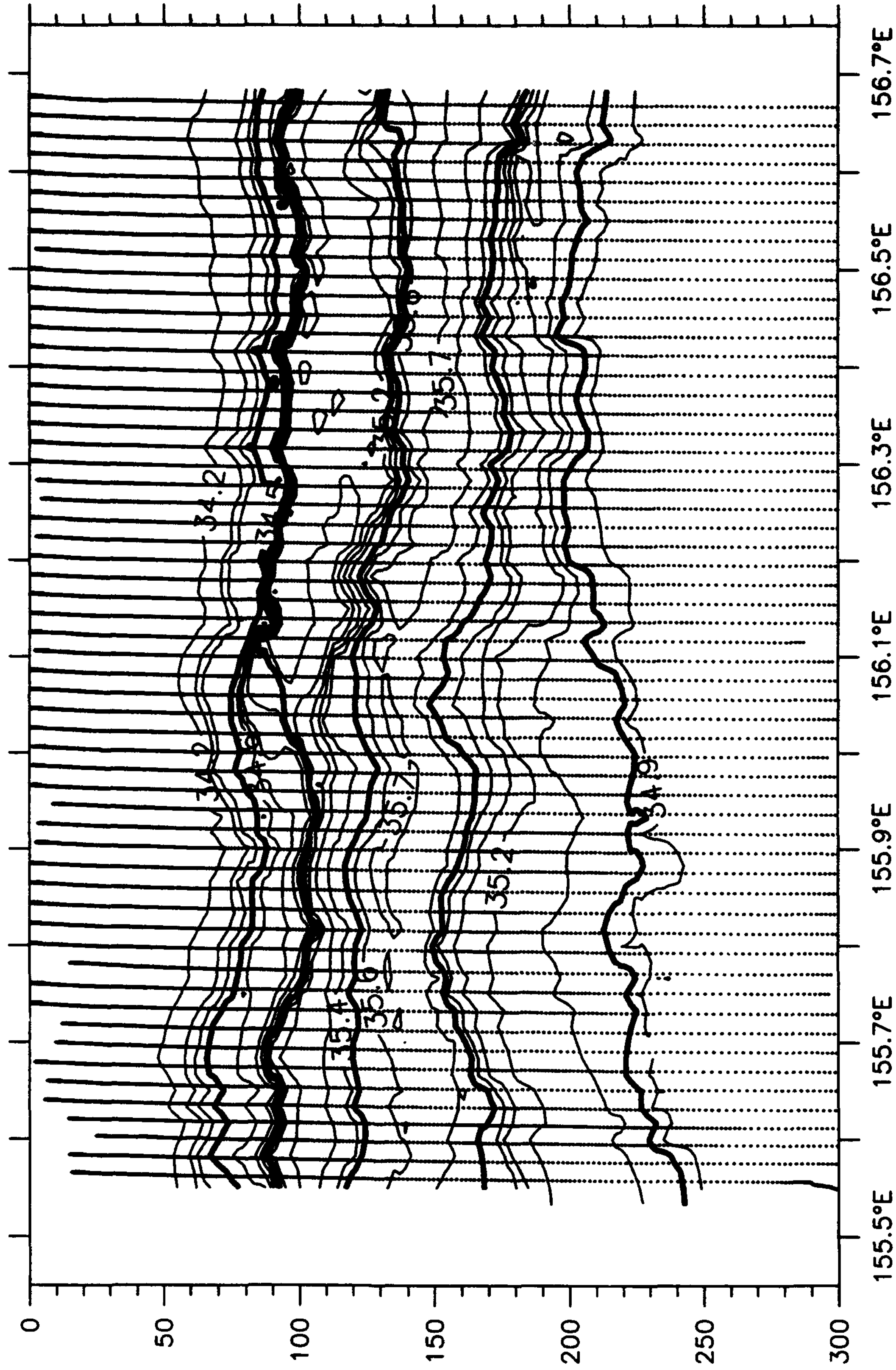
S(psu), W2E, 29 January 1993



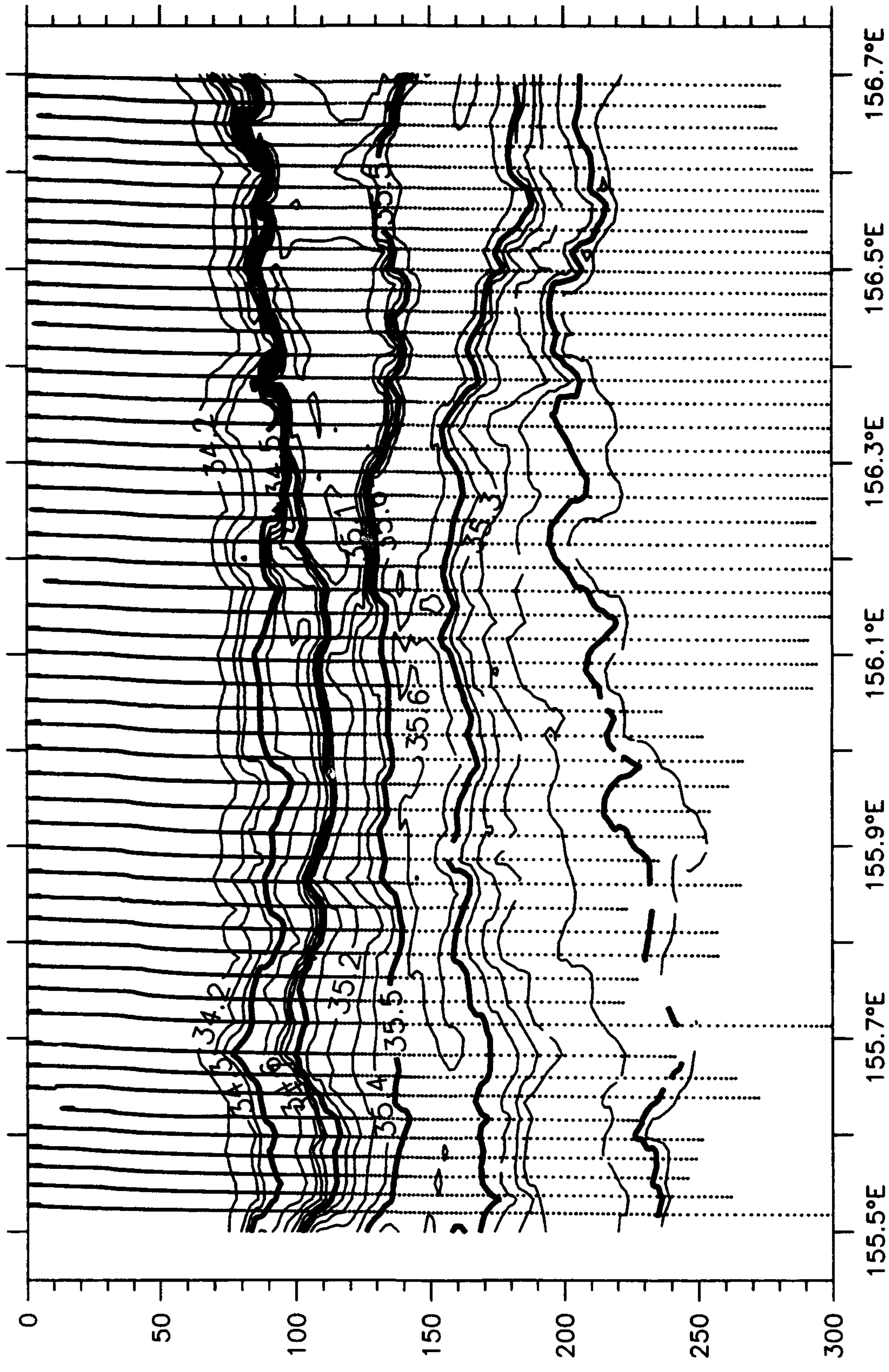
S(psu), W2E, 31 January 1993



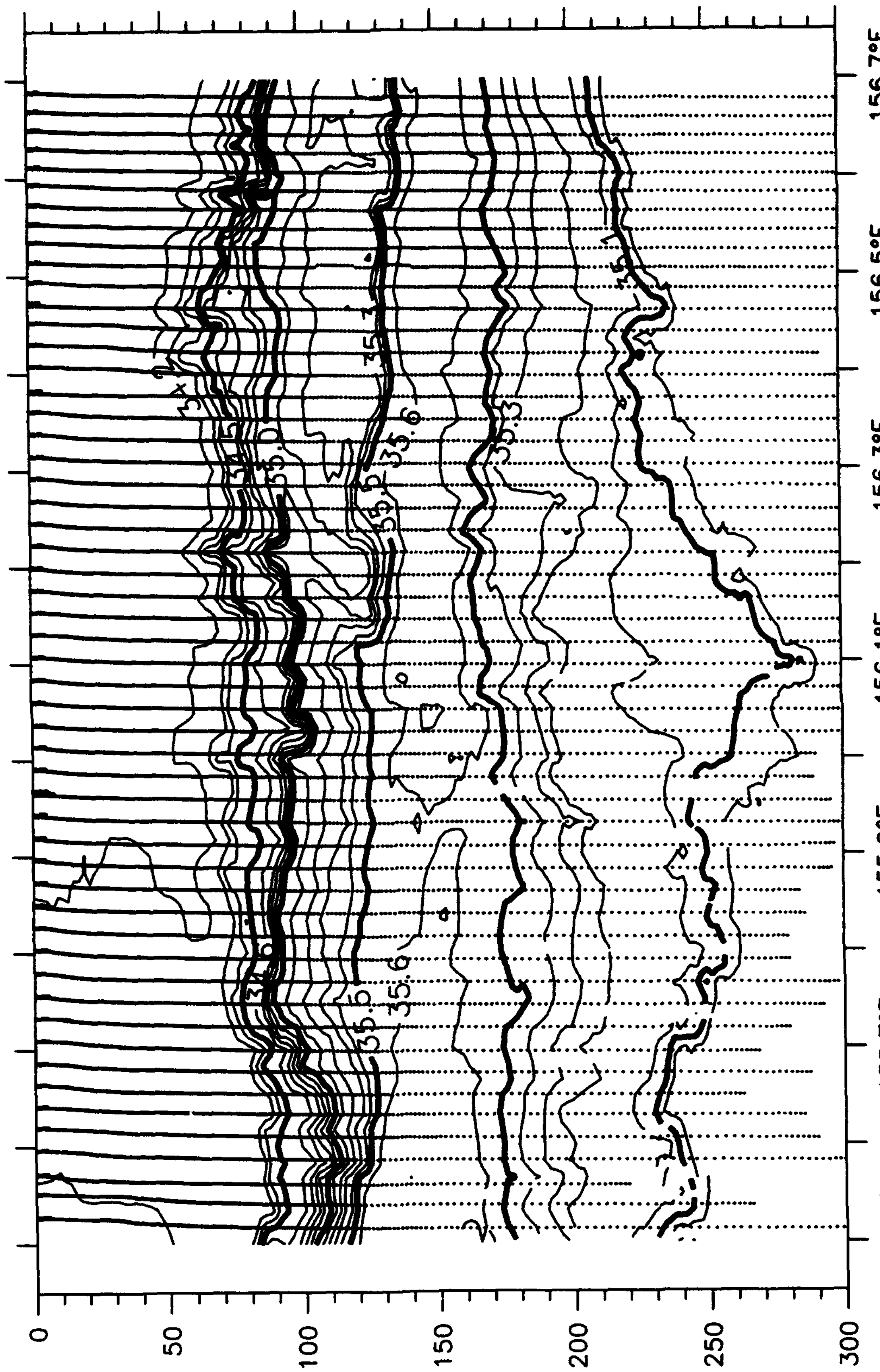
S(psu), W2E, 1 February 1993



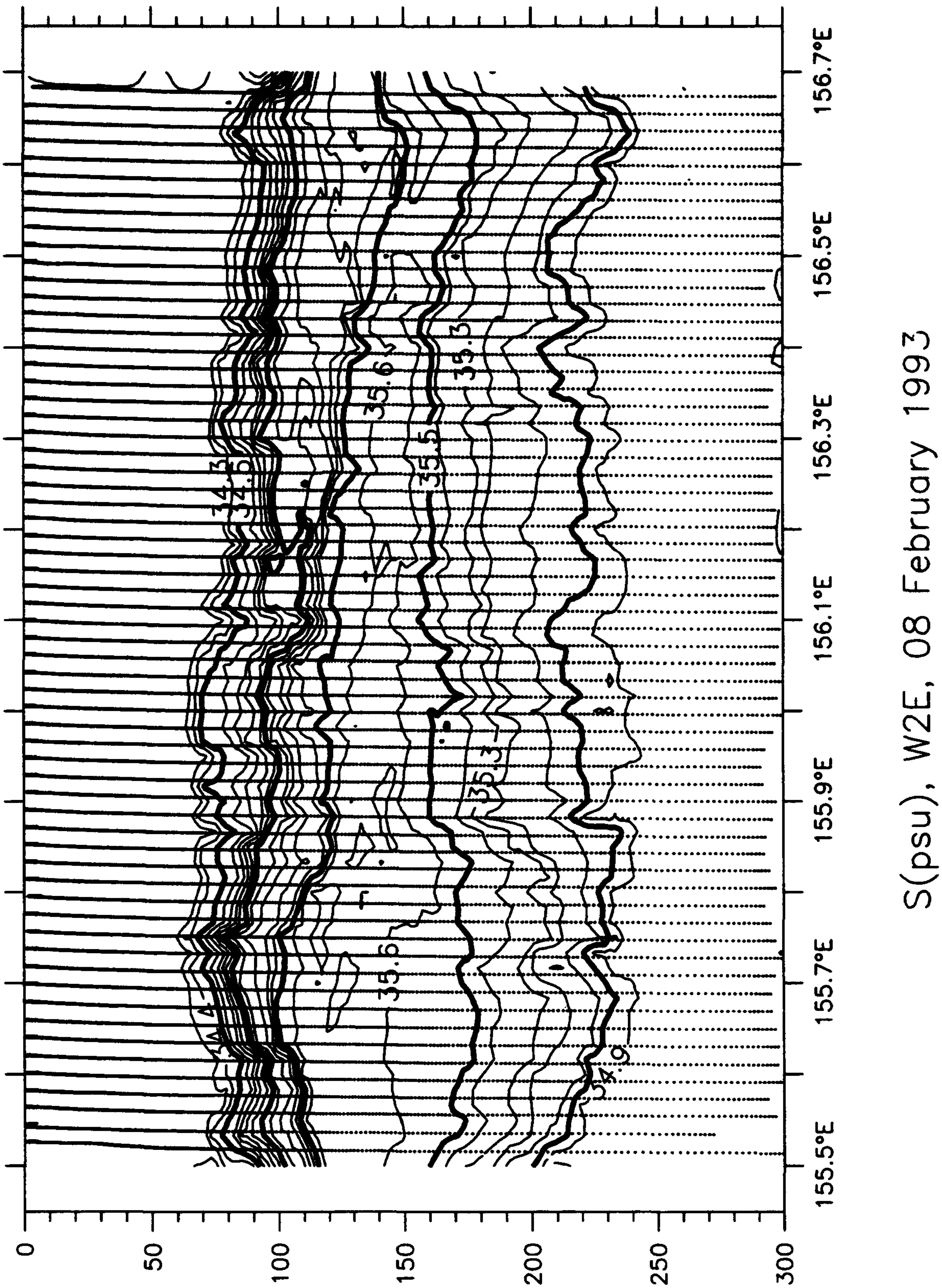
S(psu), W2E, 3 February 1993



S(psu), W2E, 04 February 1993



S(psu), W2E, 06 February 1993


S(psu), W2E, 08 February 1993
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155.7°E
155.9°E
156.1°E
156.3°E
156.5°E
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100
150
200
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34.3
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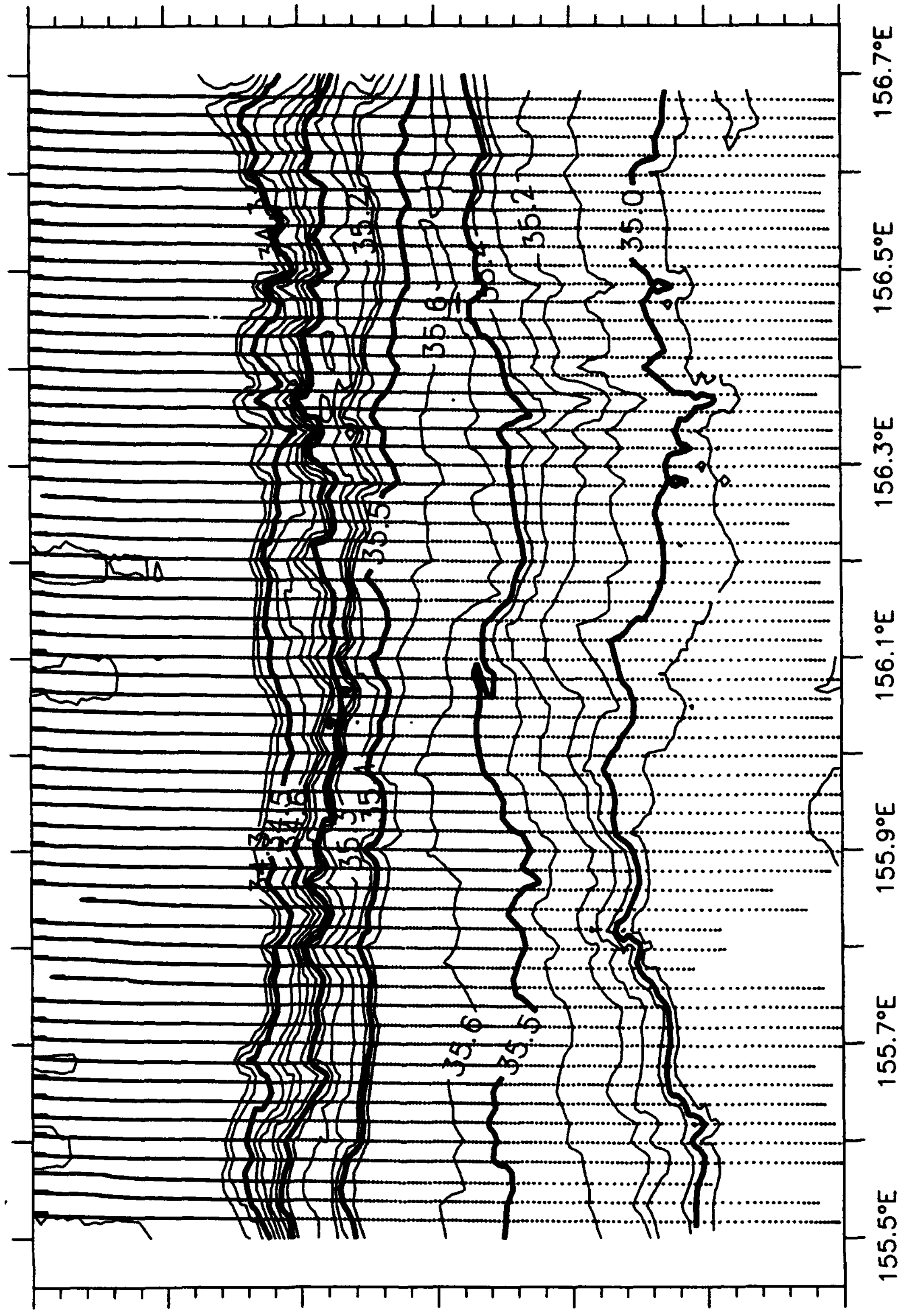
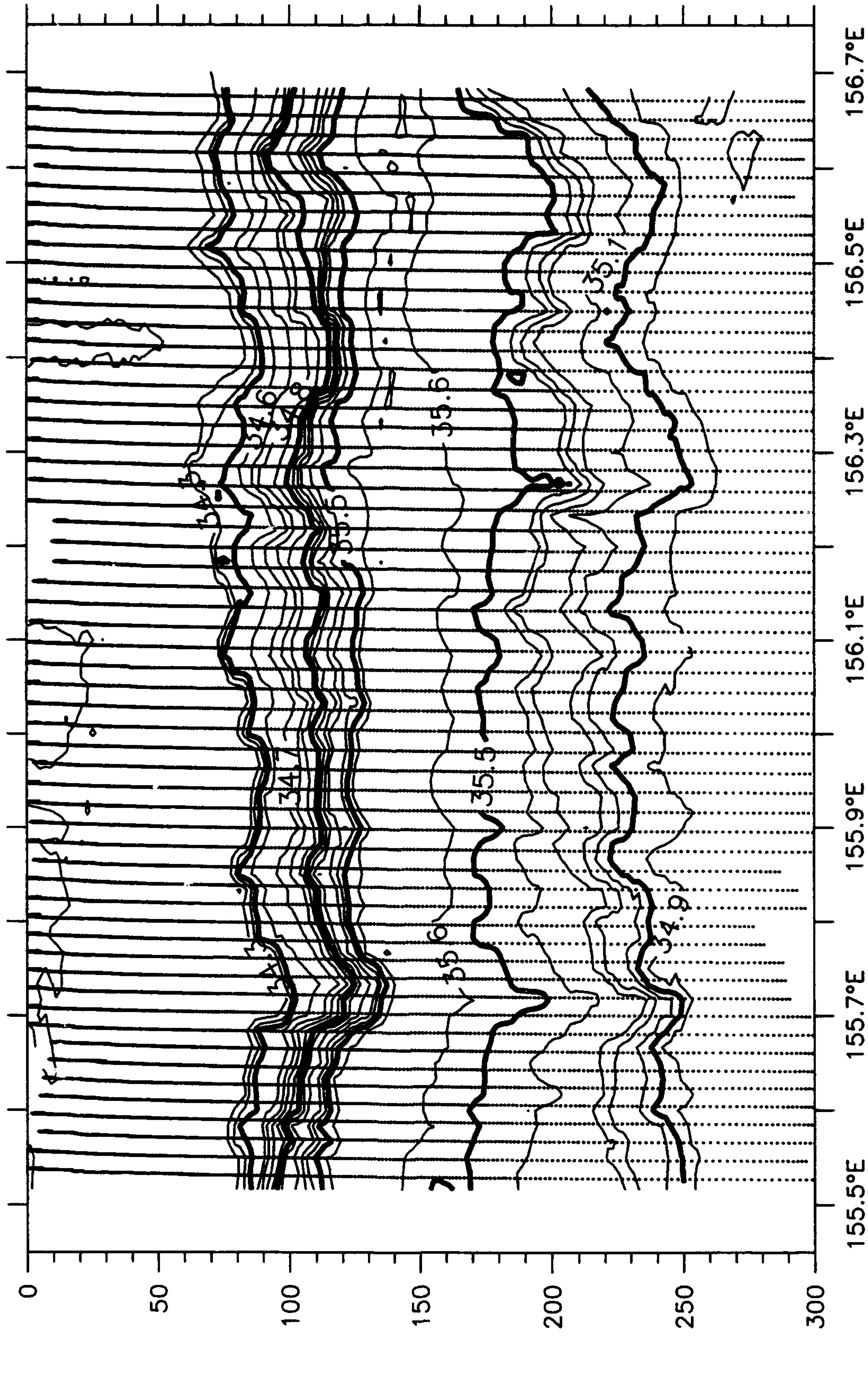
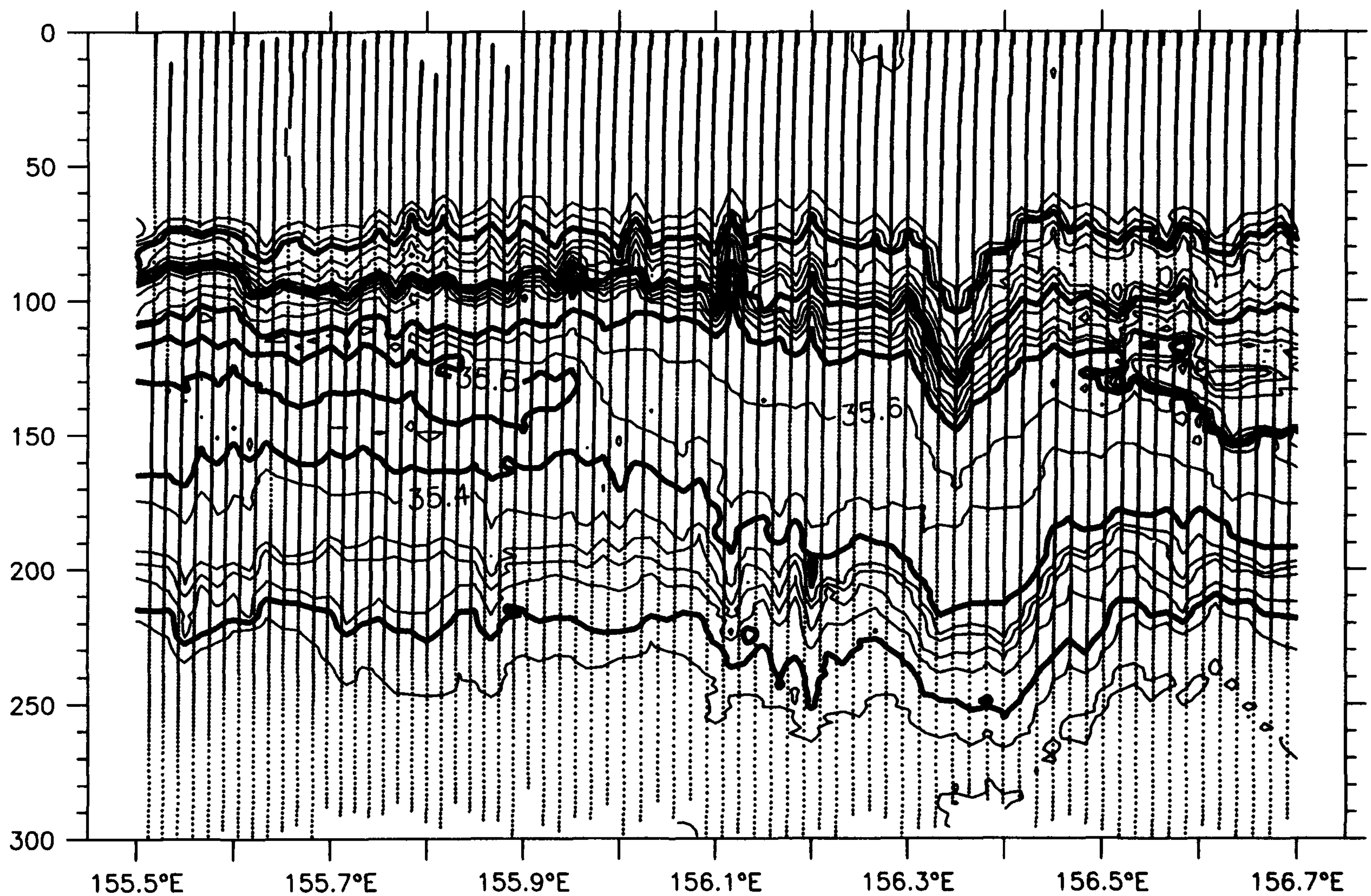
34.4
34.9
35.6
35.5
35.3



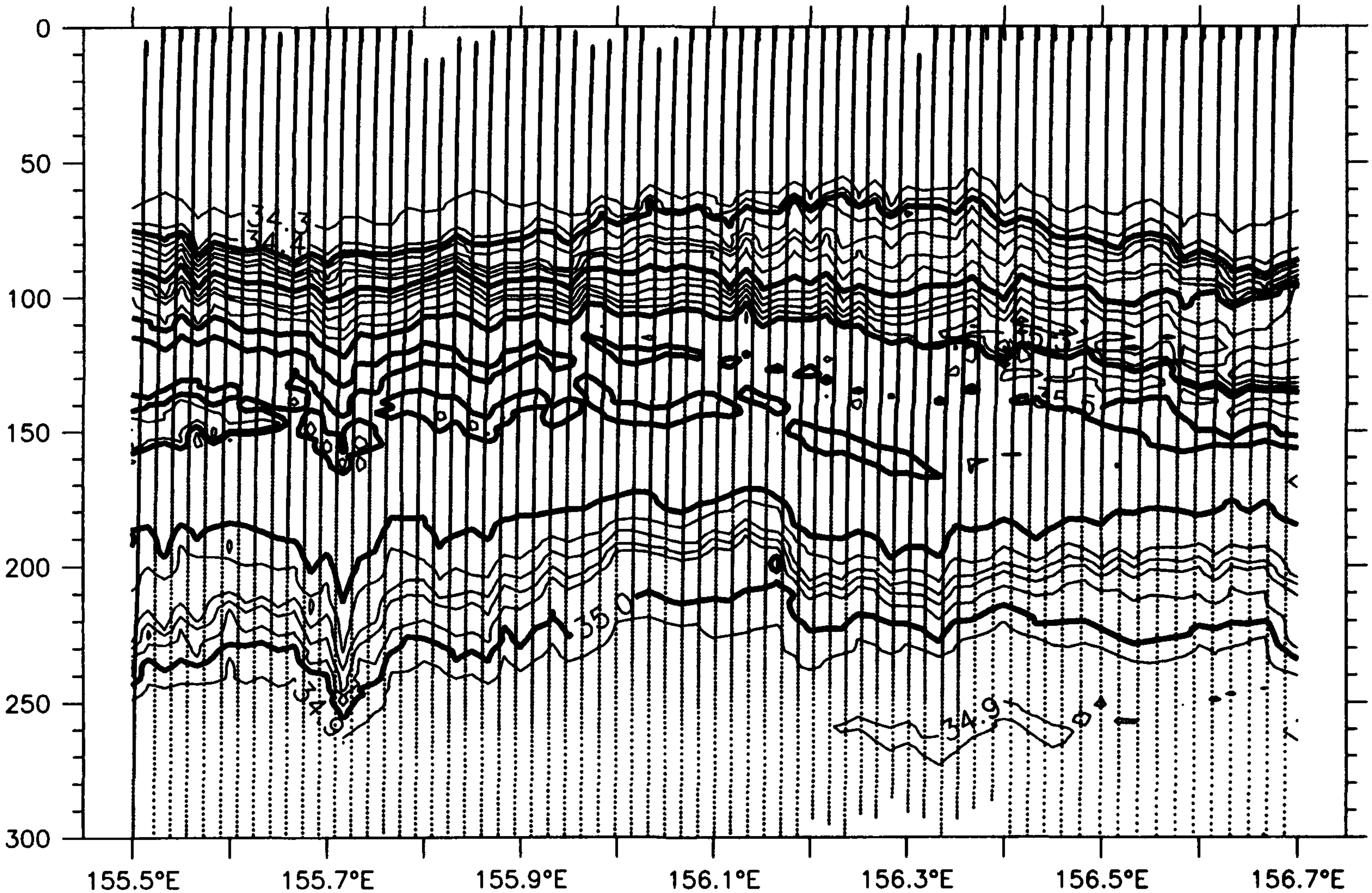
S(psu), W2E, 10 February 1993



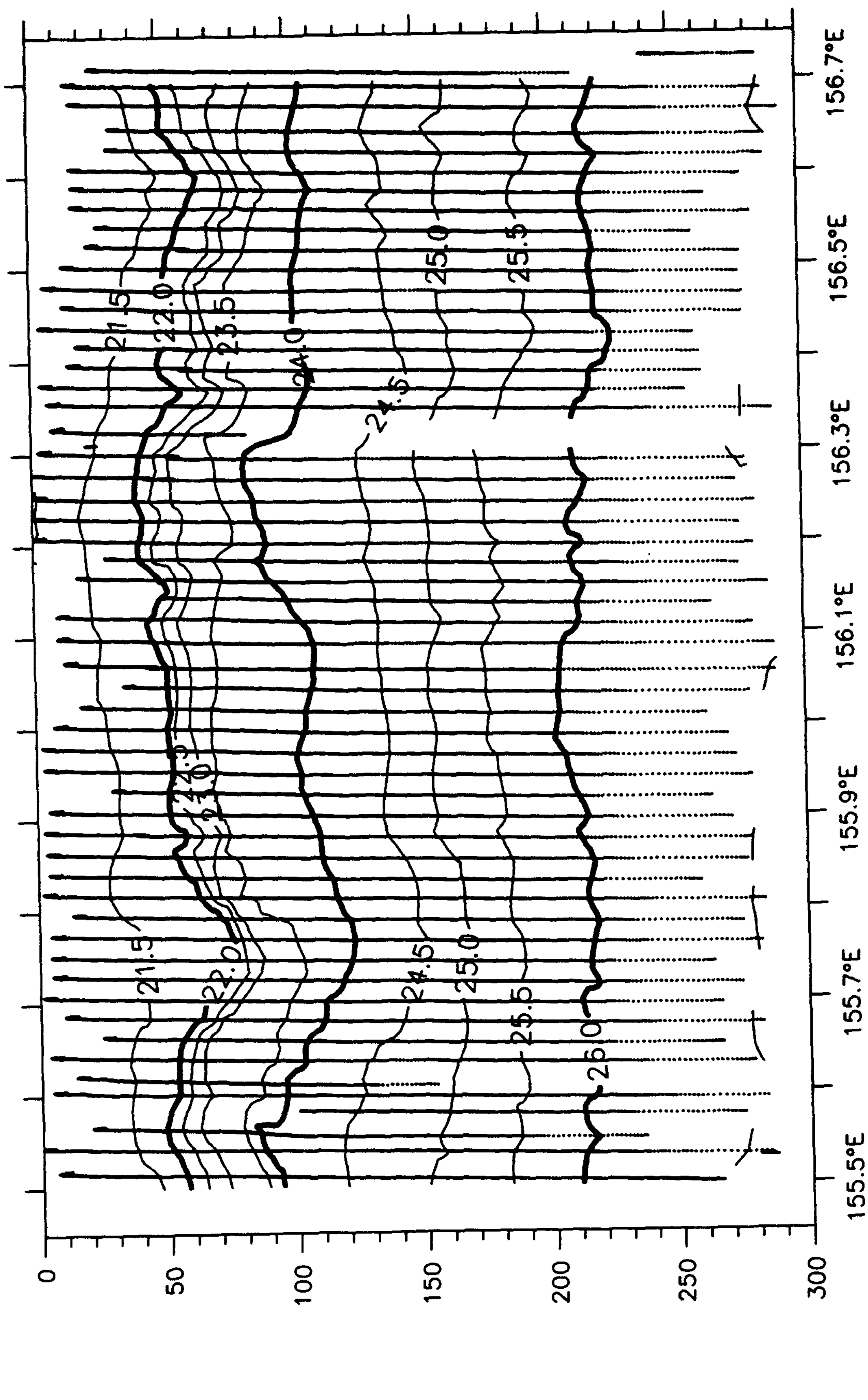
S(psu), W2E, 11 February 1993



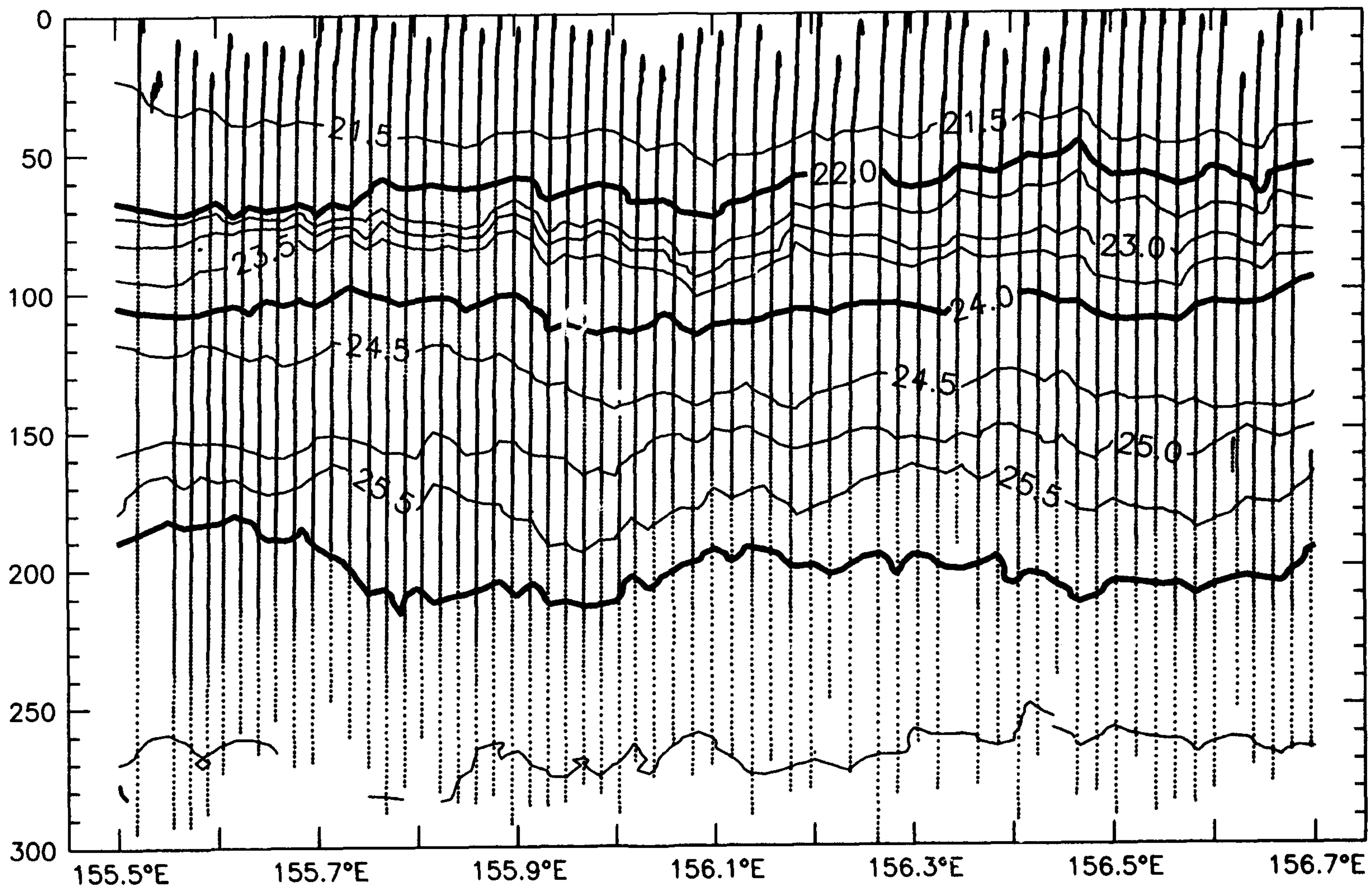
S(psu), W2E, 13 February 1993



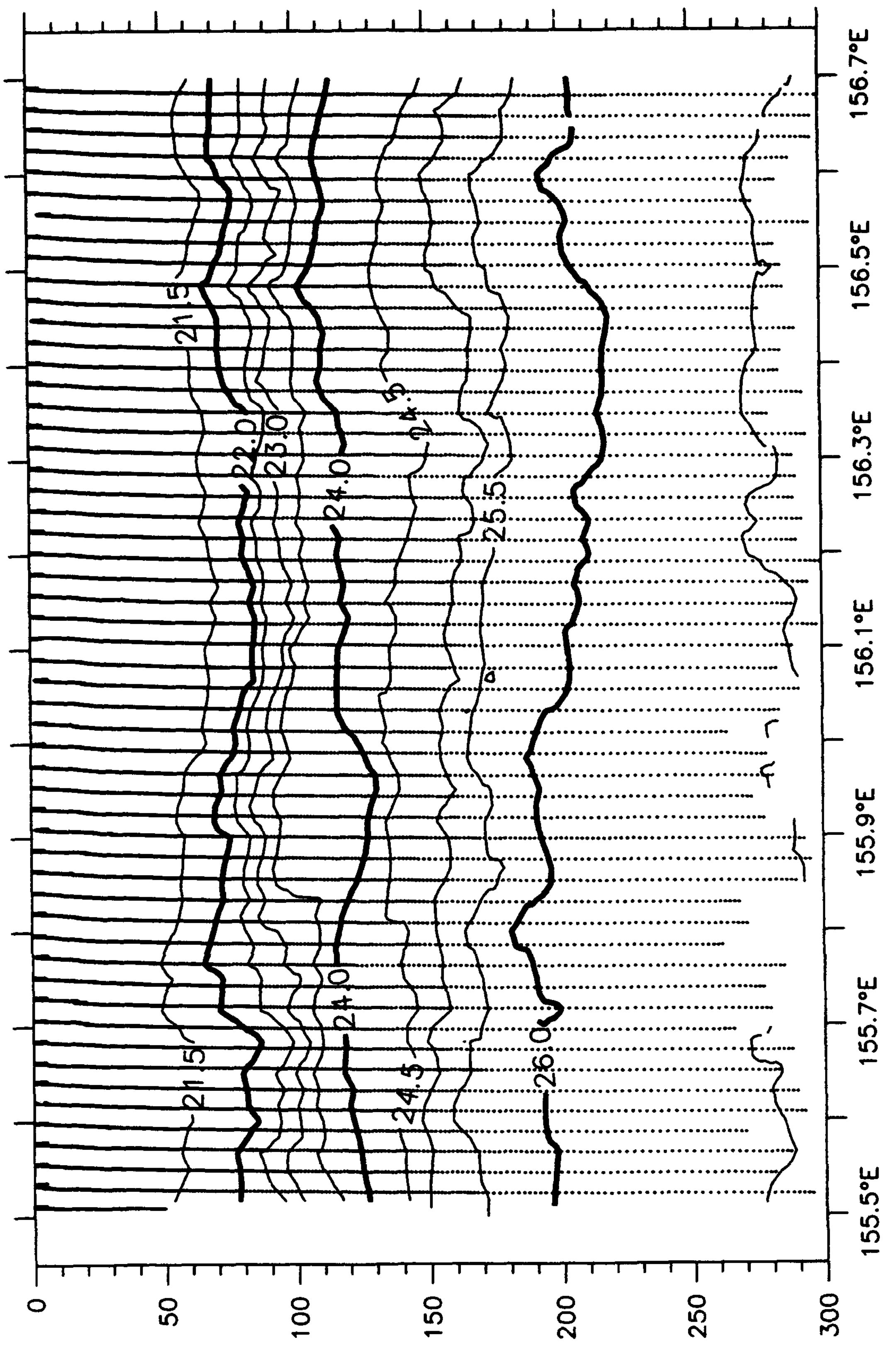
S(psu), W2E, 14 February 1993



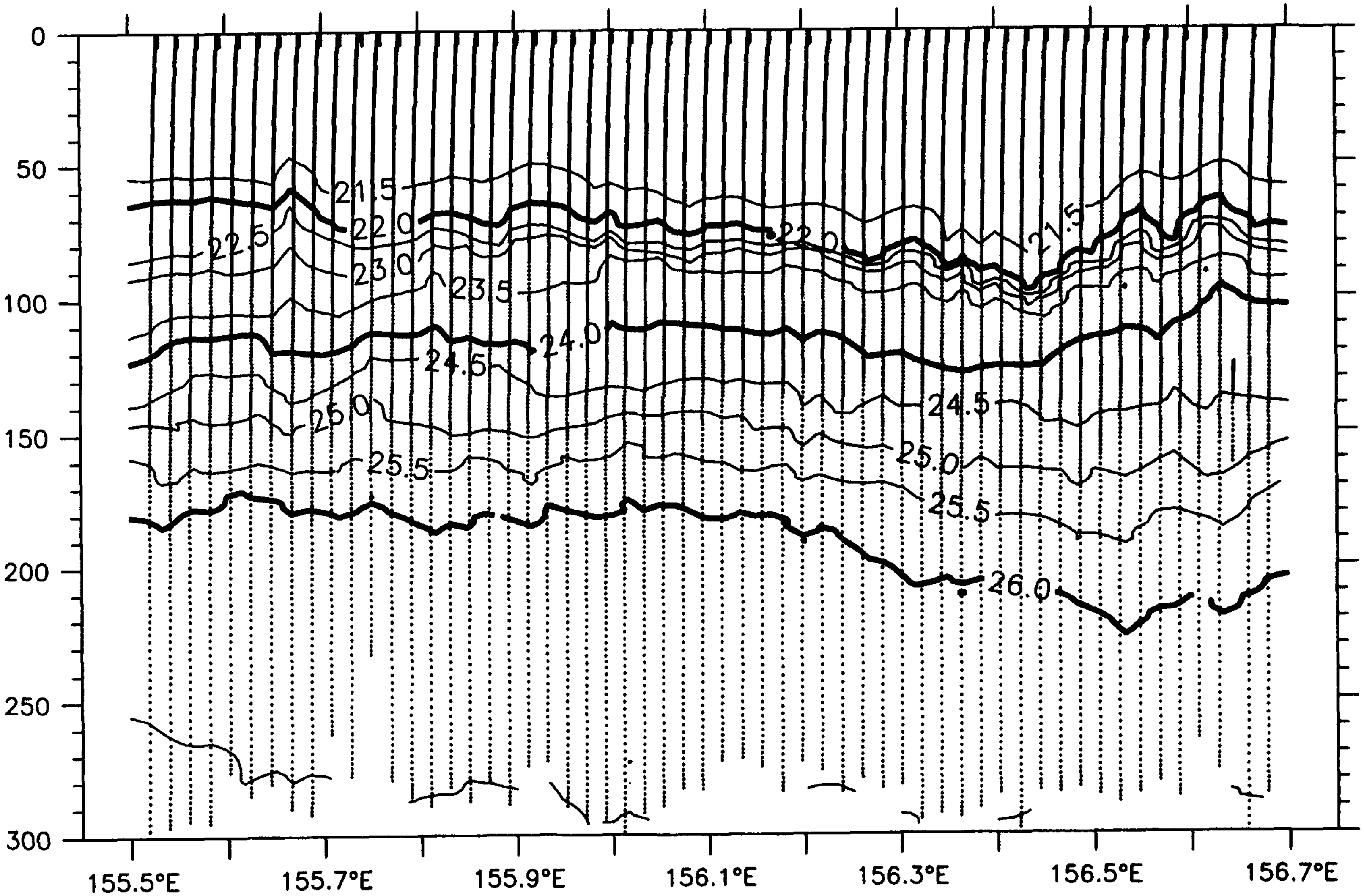
Sigma-t, W2E, 28 January 1993



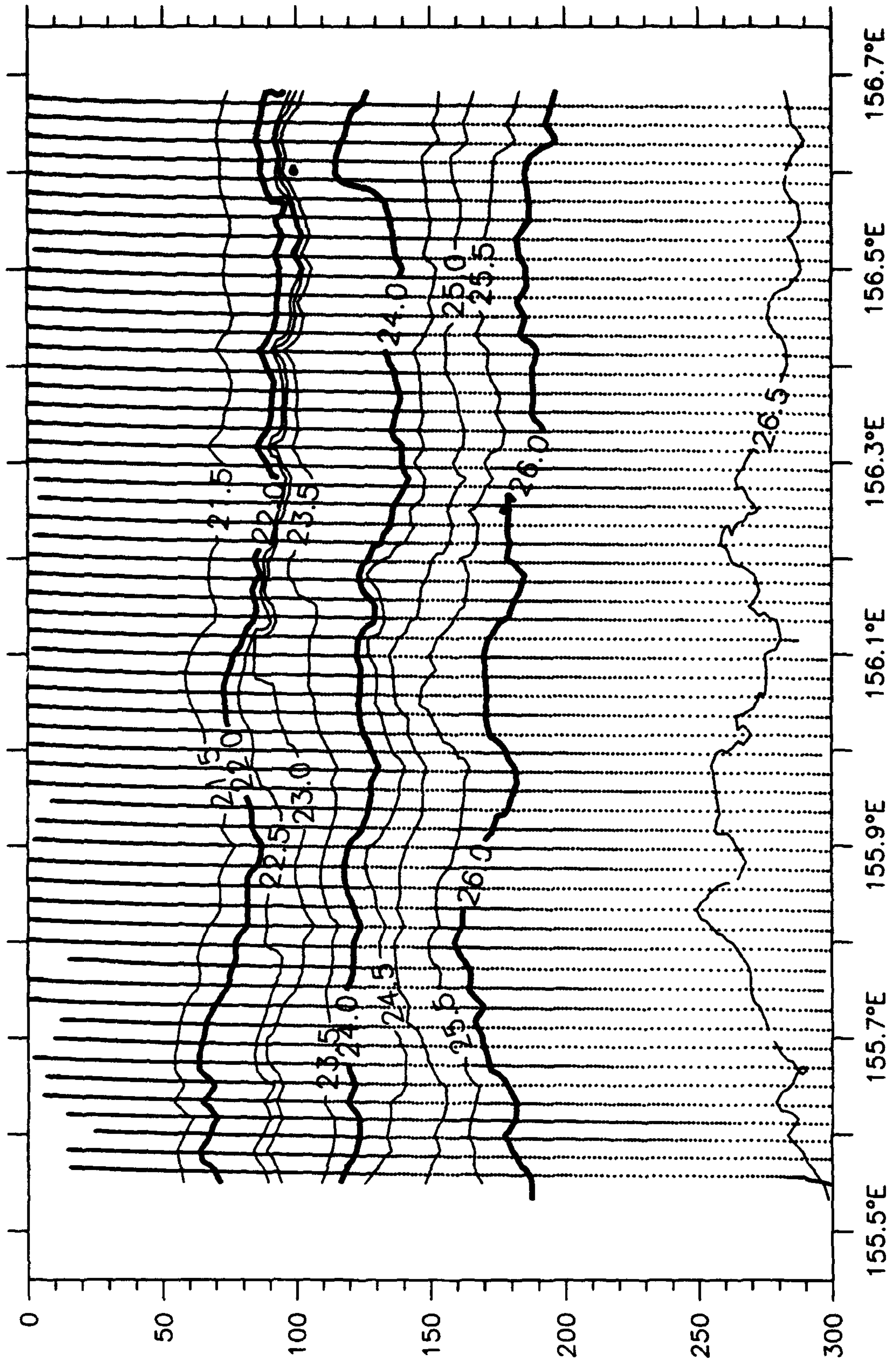
Sigma-t, W2E, 29 January 1993



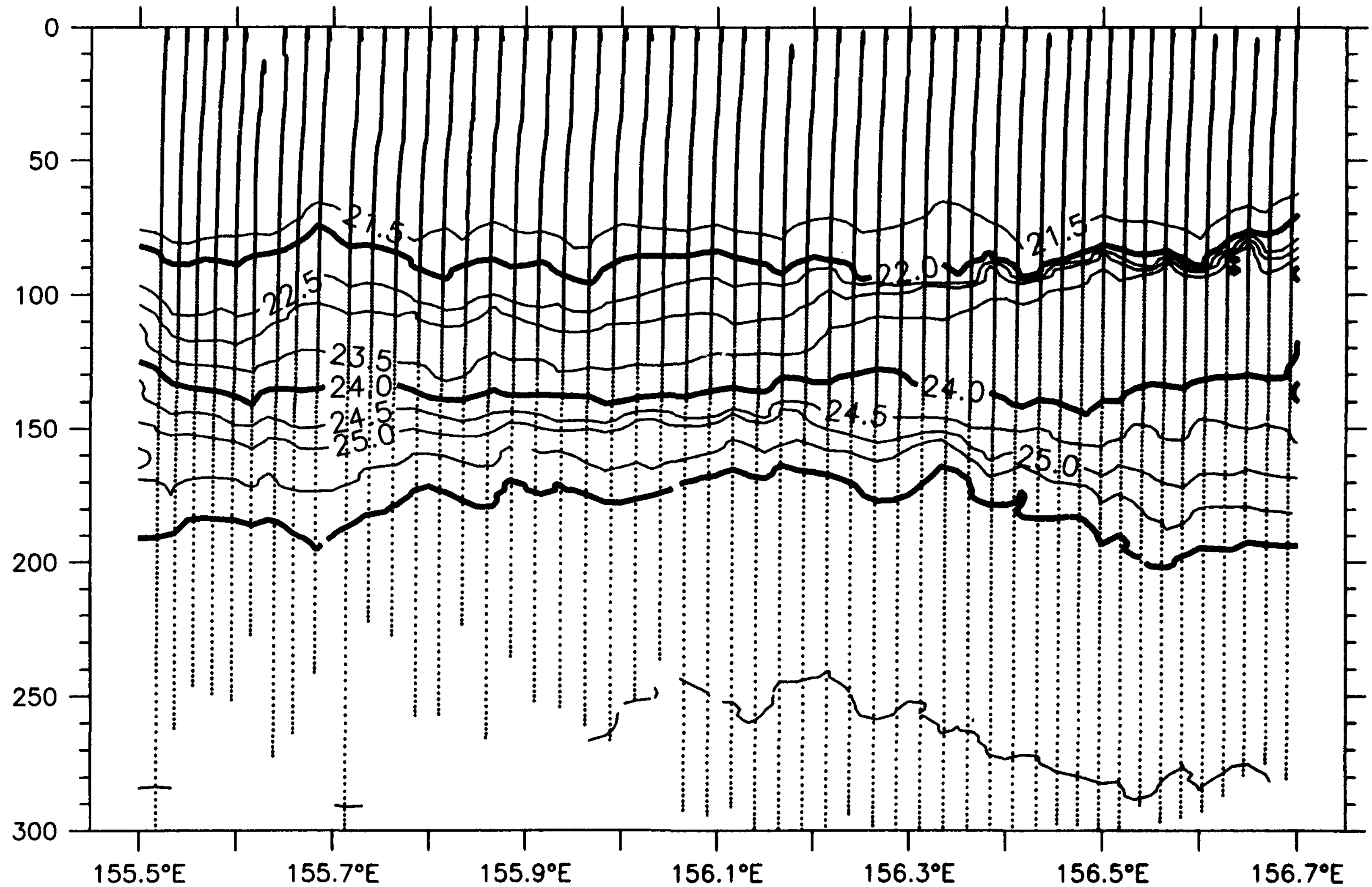
Sigma−t, W2E, 31 January 1993



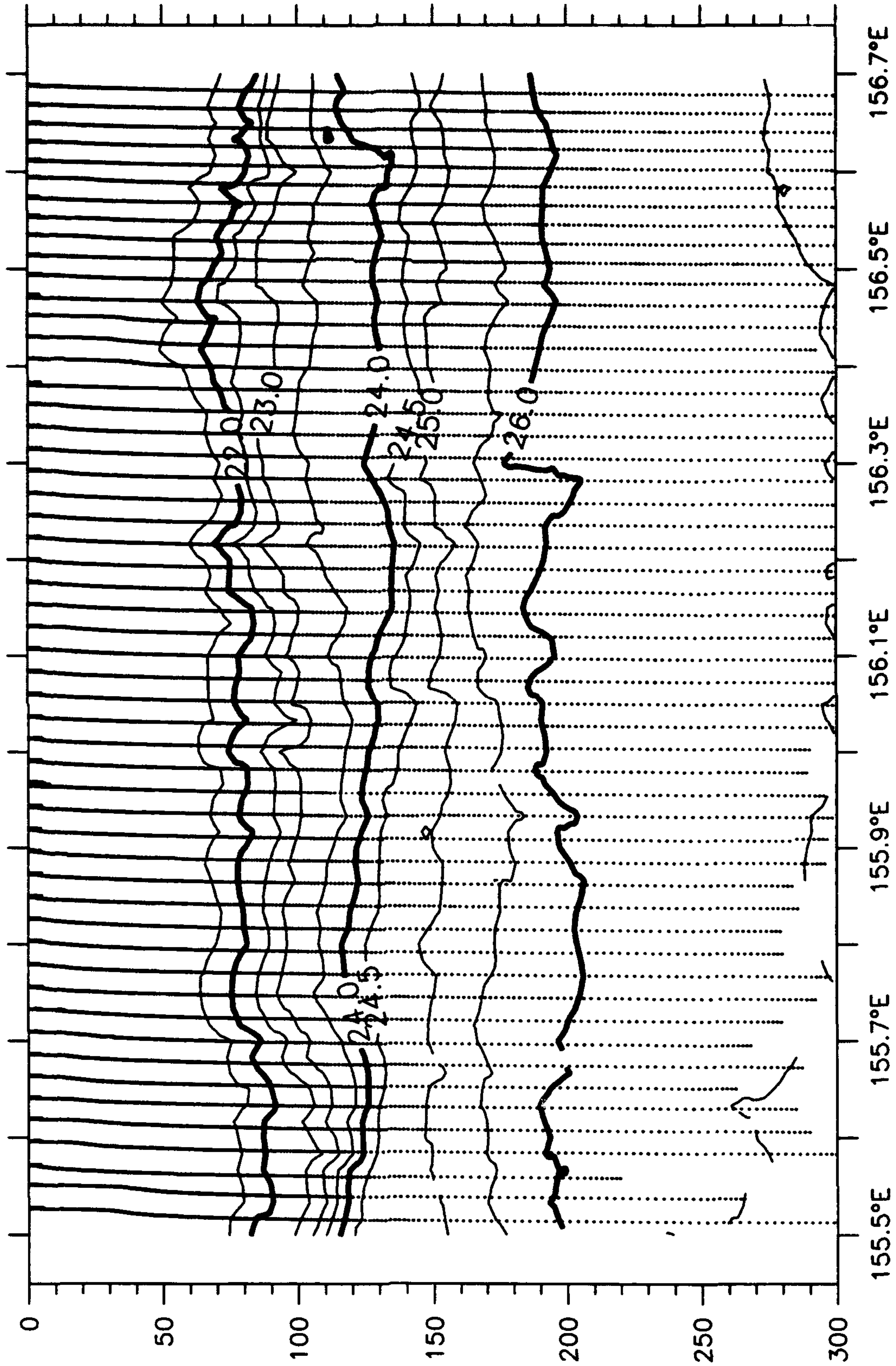
Sigma–t, W2E, 1 February 1993



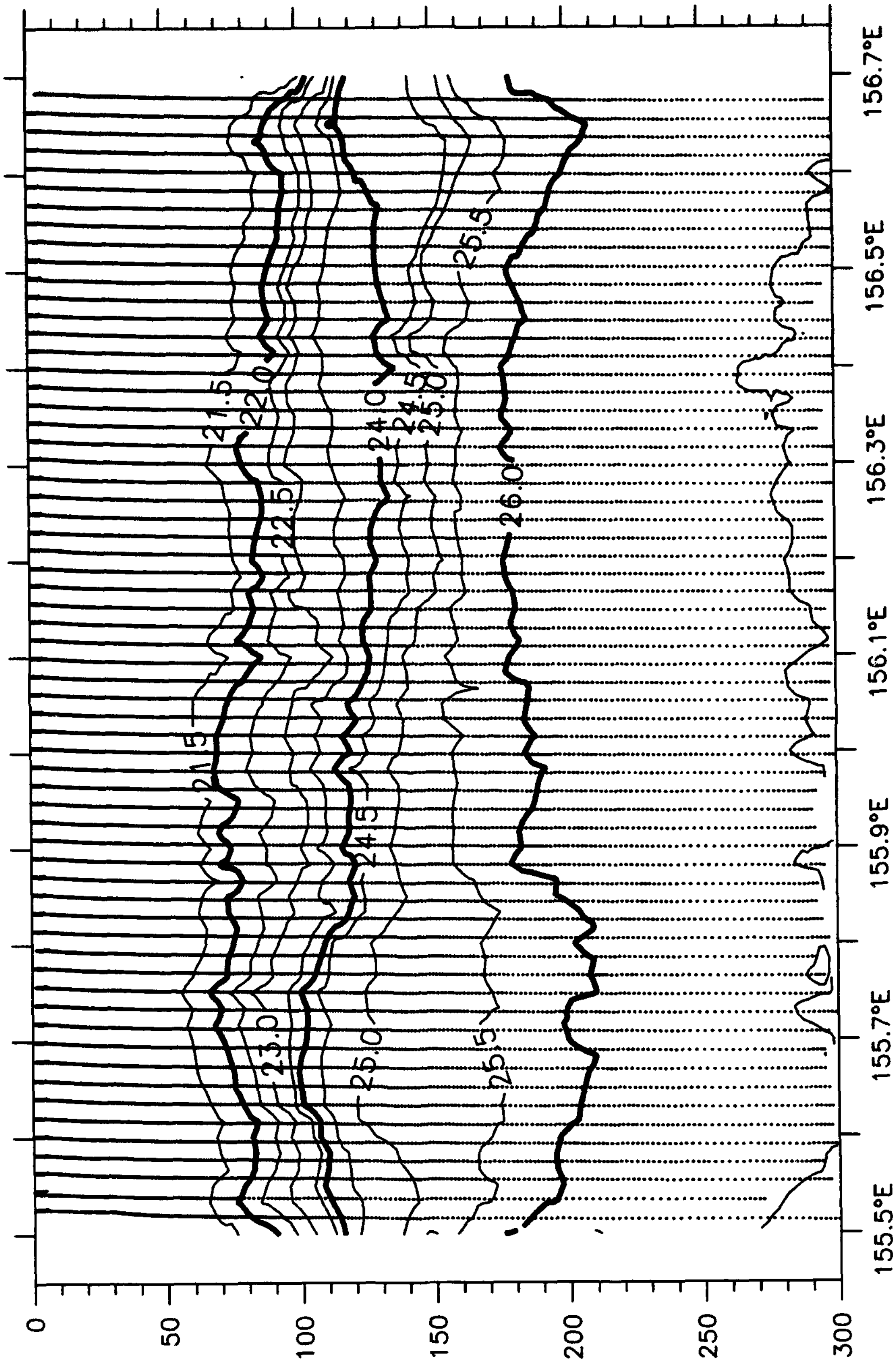
Sigma–t, W2E, 3 February 1993



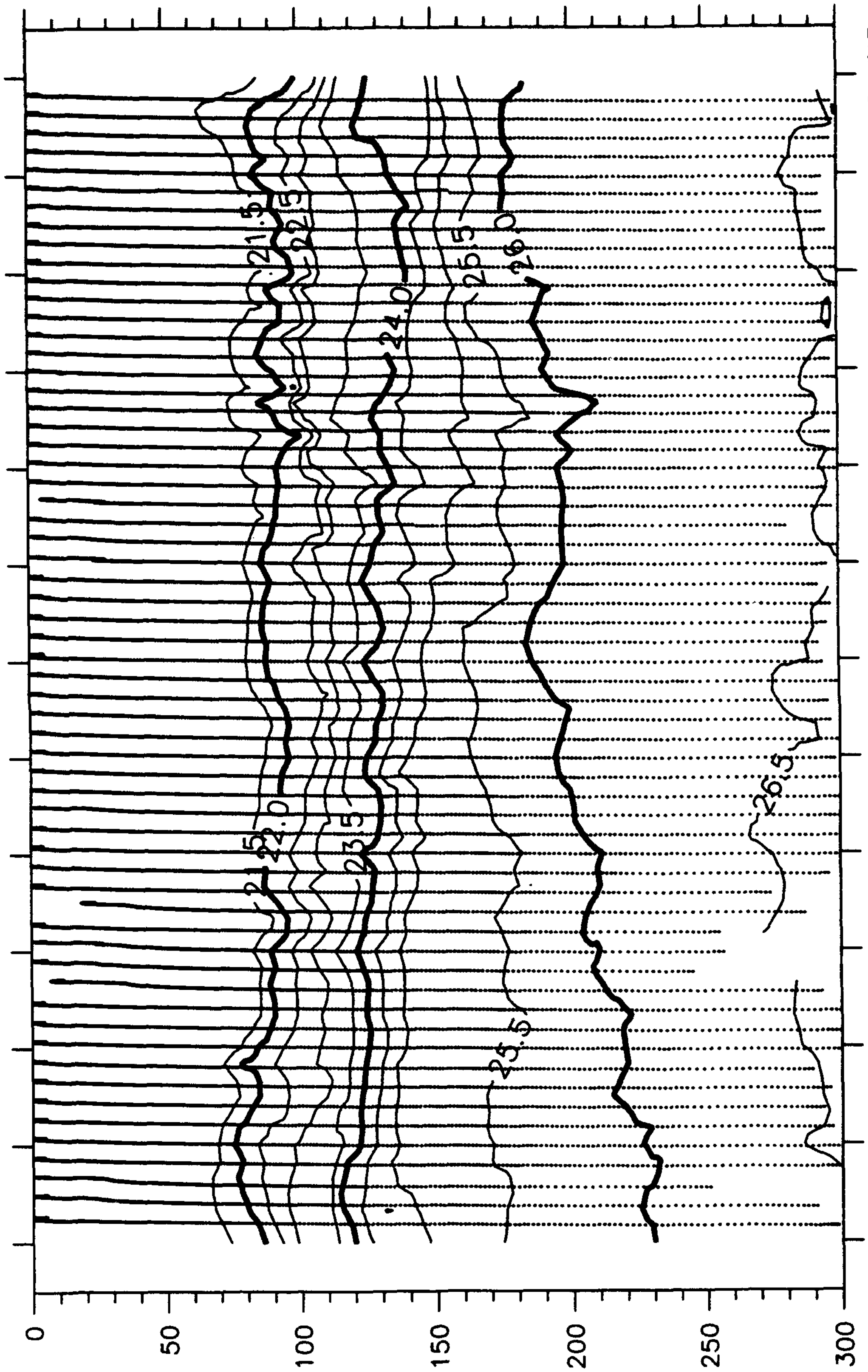
Sigma–t, W2E, 04 February 1993



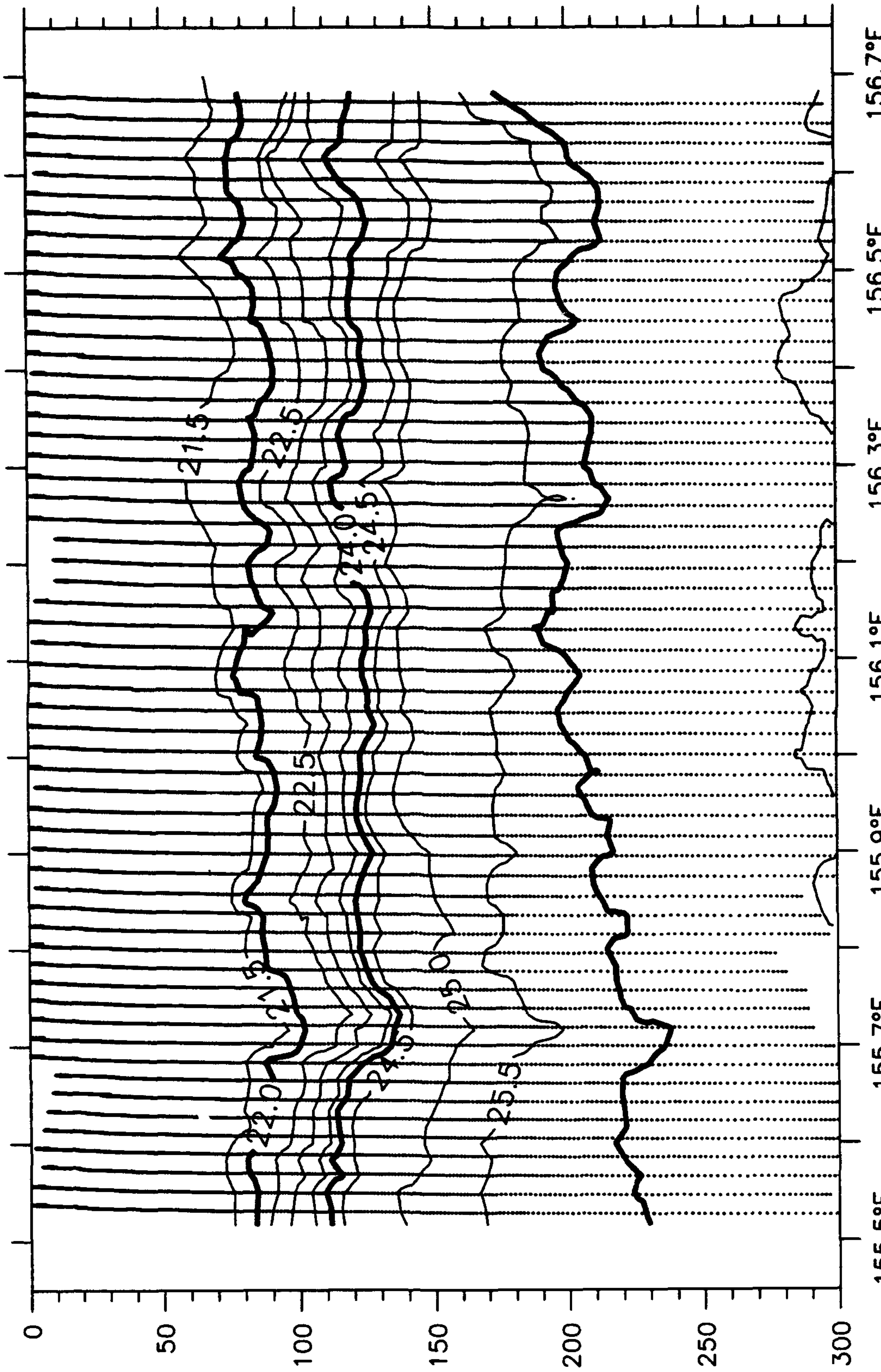
Sigma-t, W2E, 06 February 1993



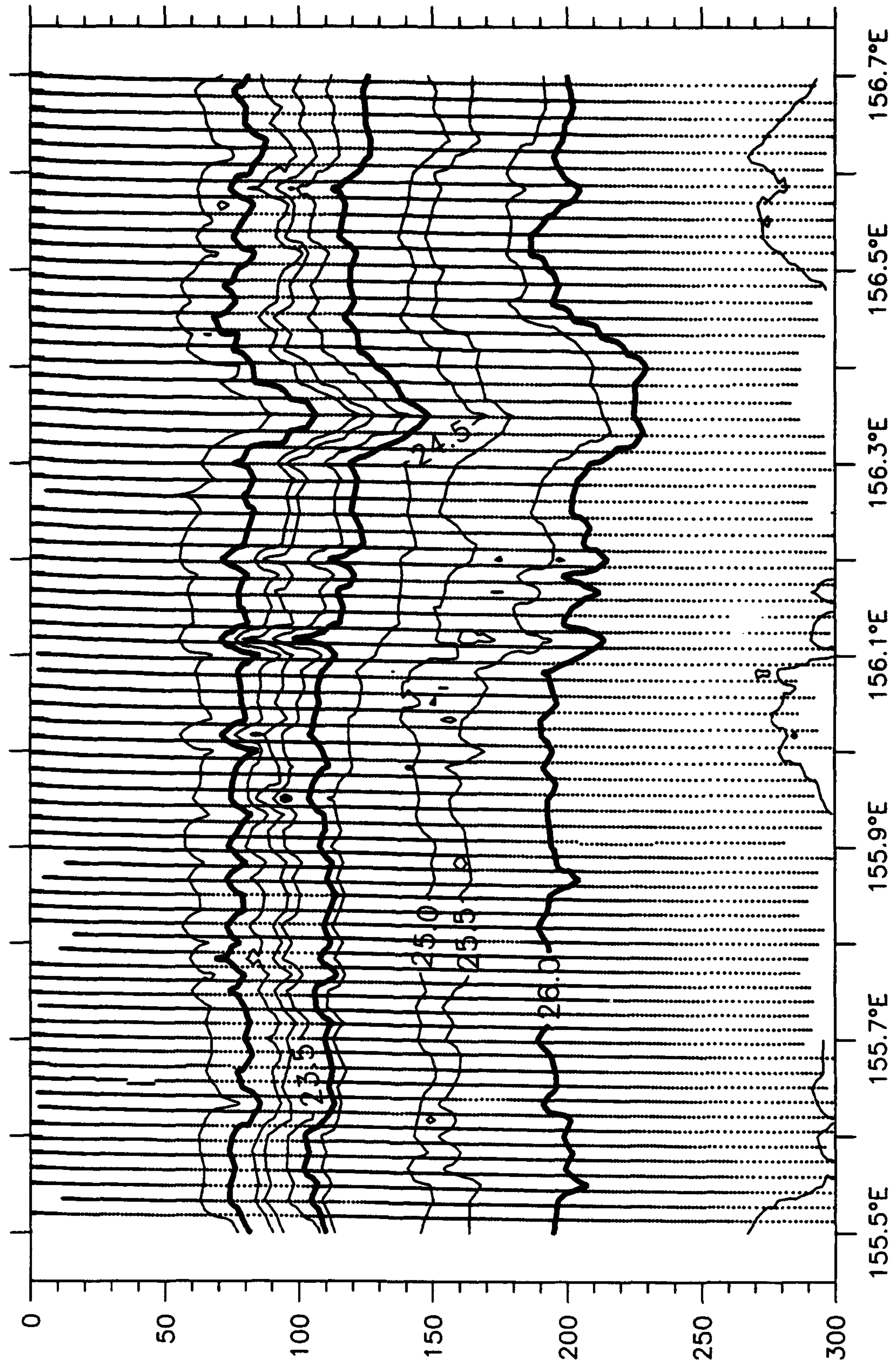
Sigma-t, W2E, 08 February 1993



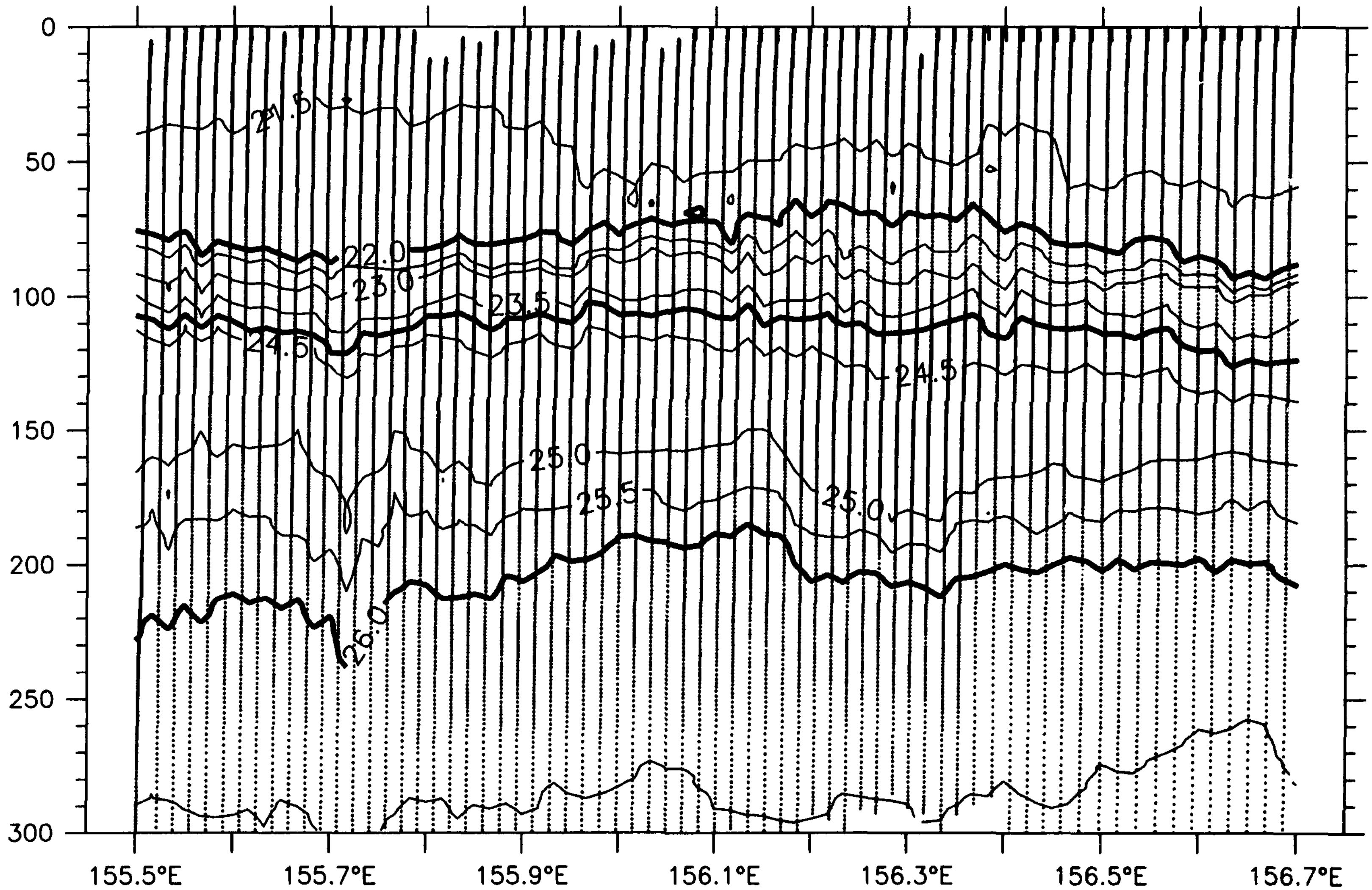
Sigma-t, W2E, 10 February 1993



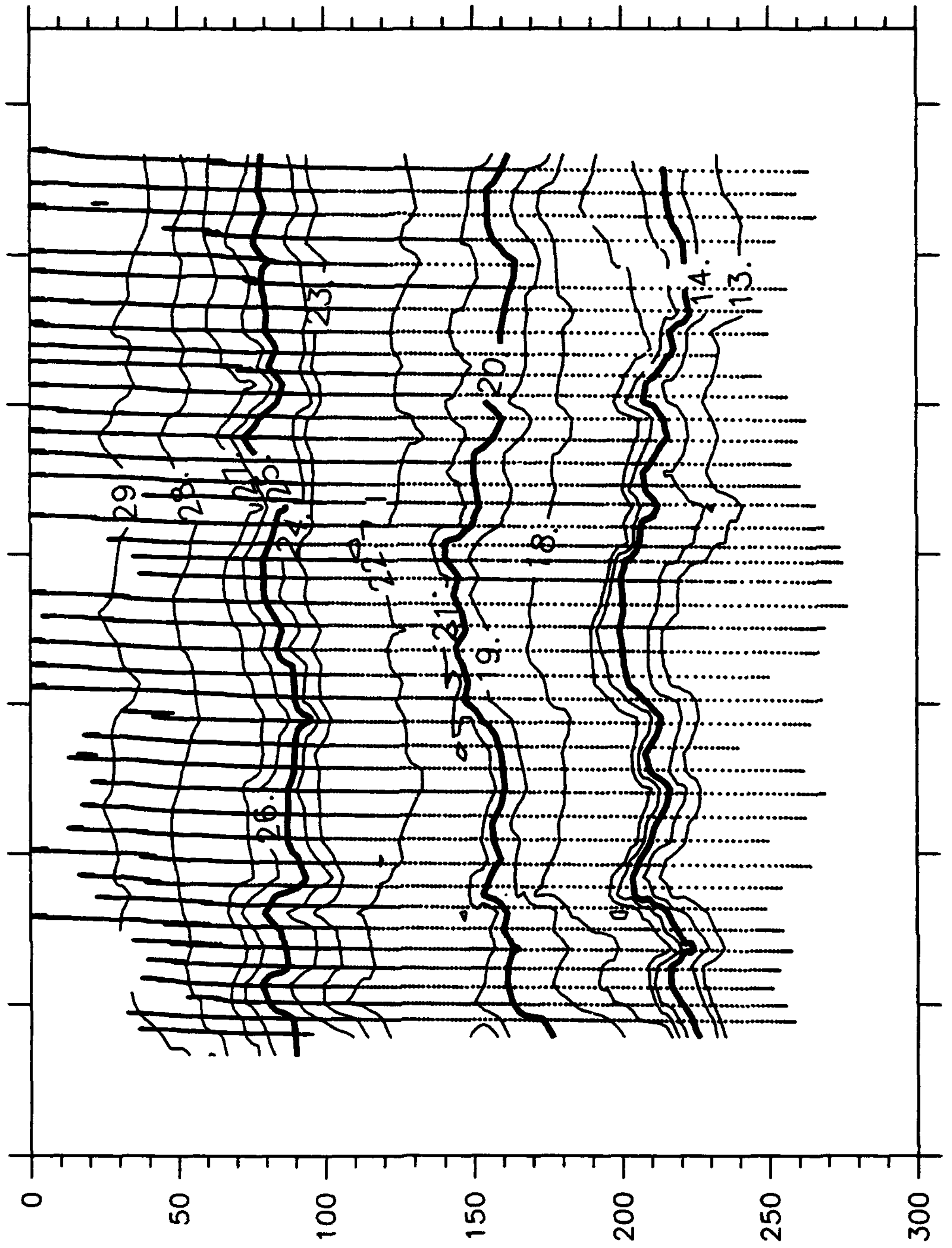
Sigma–t, W2E, 11 February 1993



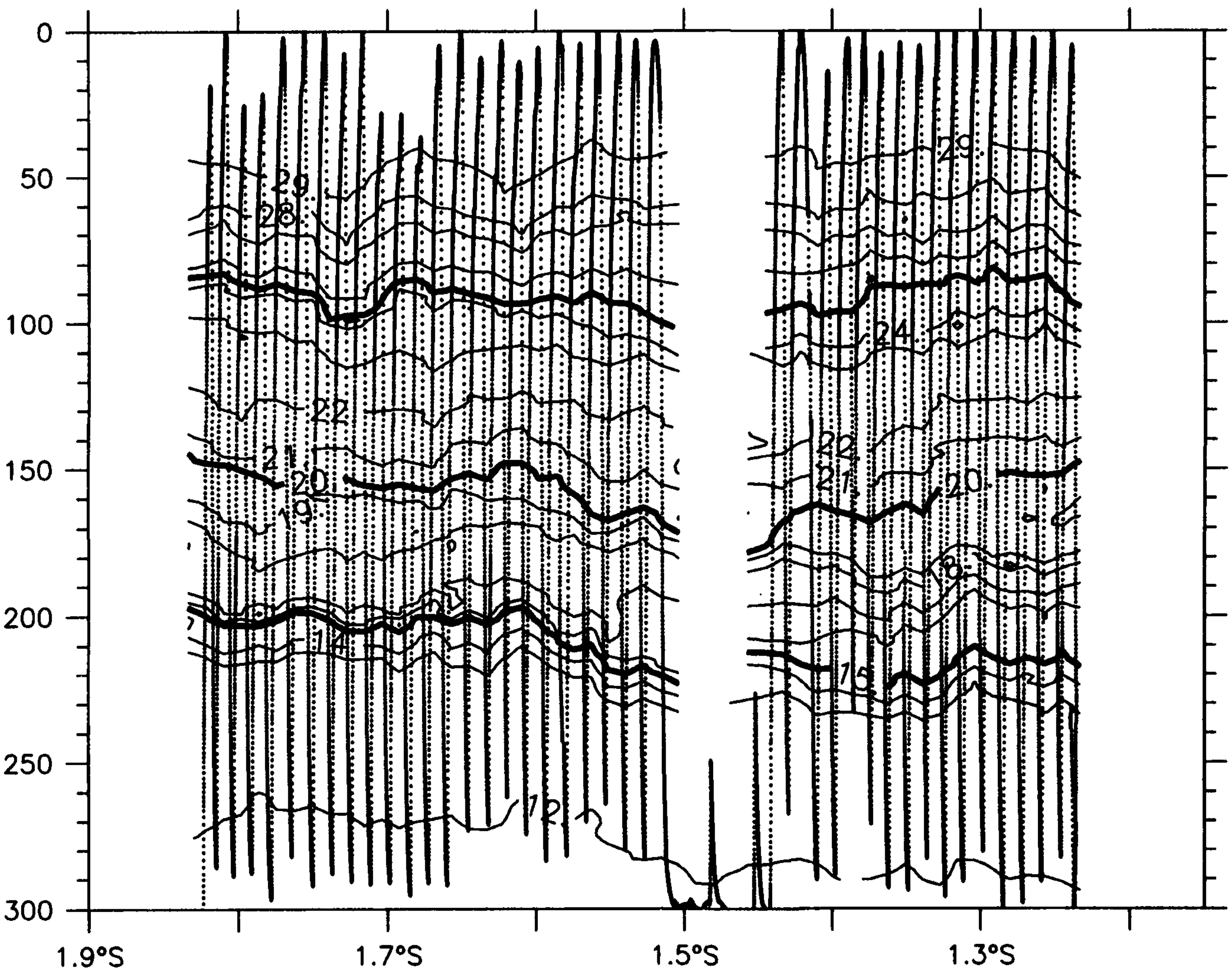
Sigma-t, W2E, 13 February 1993



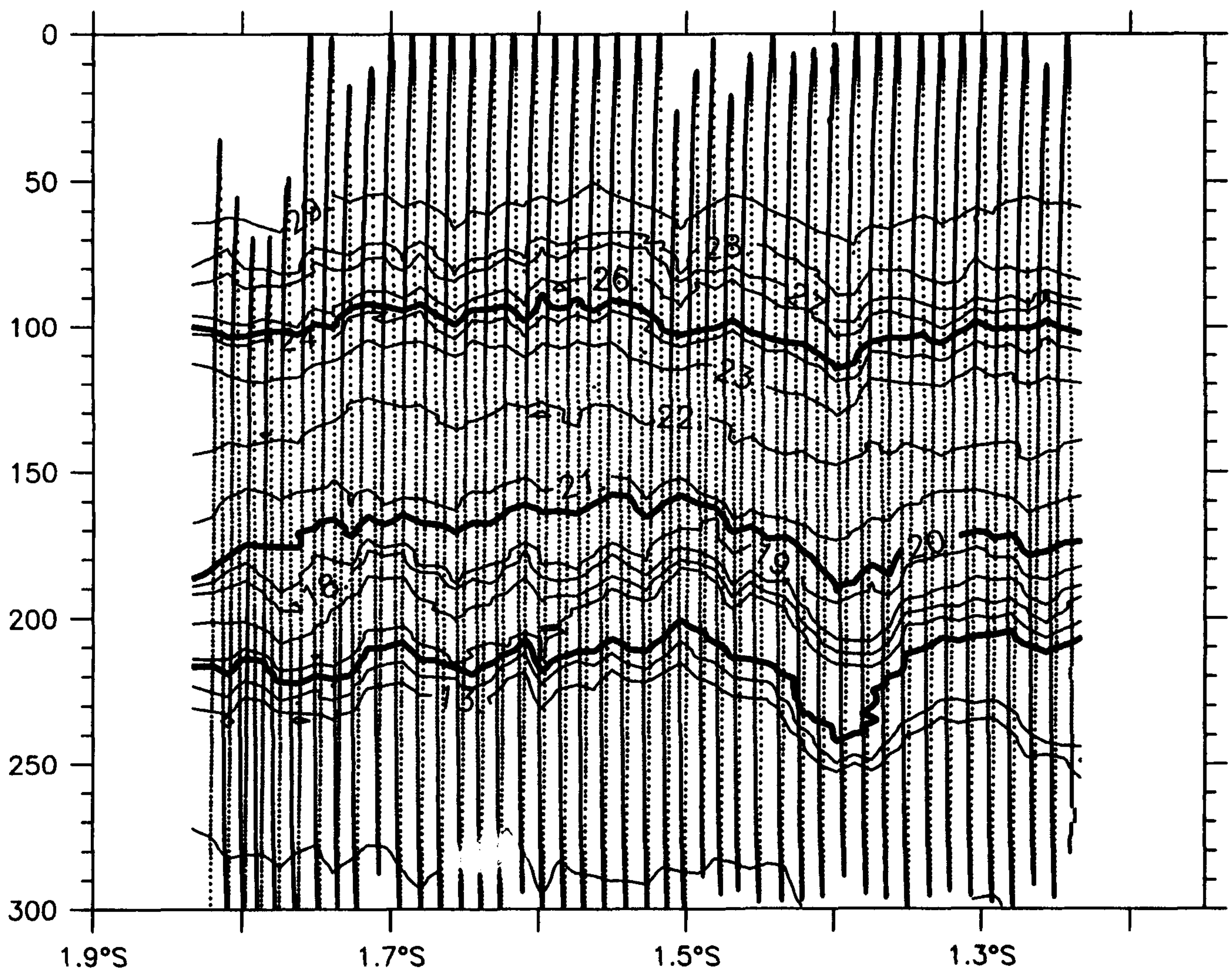
Sigma–t, W2E, 14 February 1993



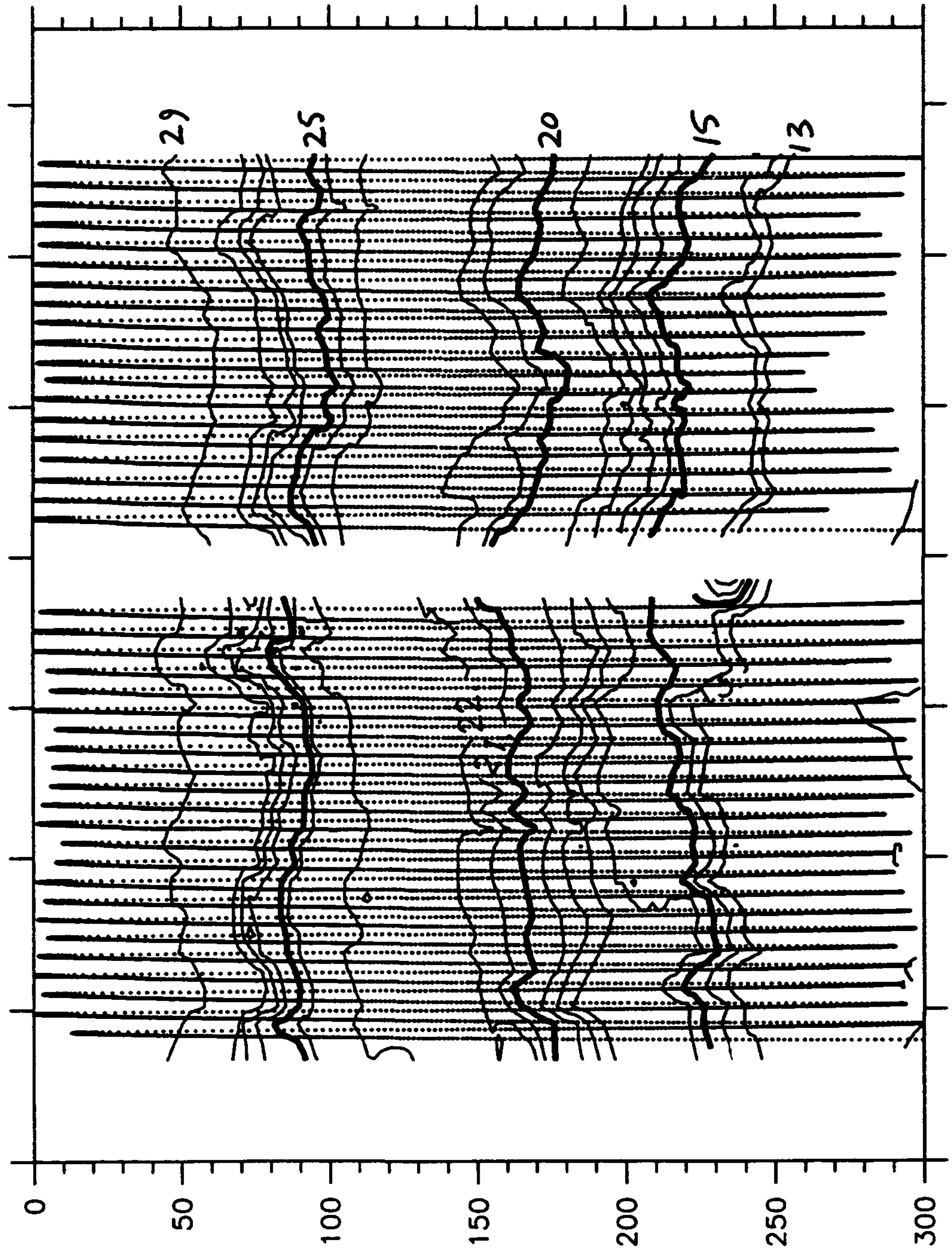
T(°C), E2N, 28 January 1993



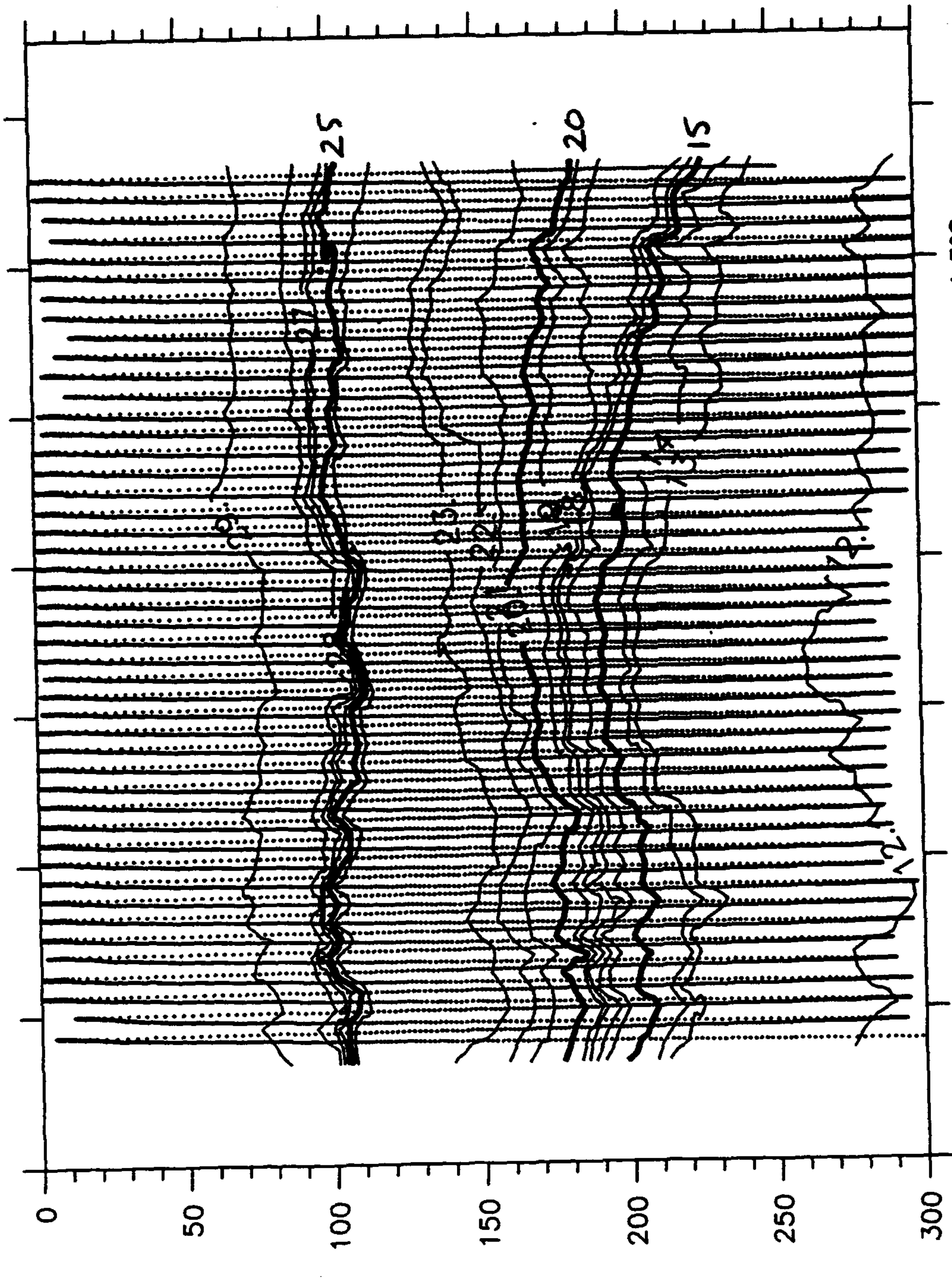
T(°C), E2N, 30 January 1993



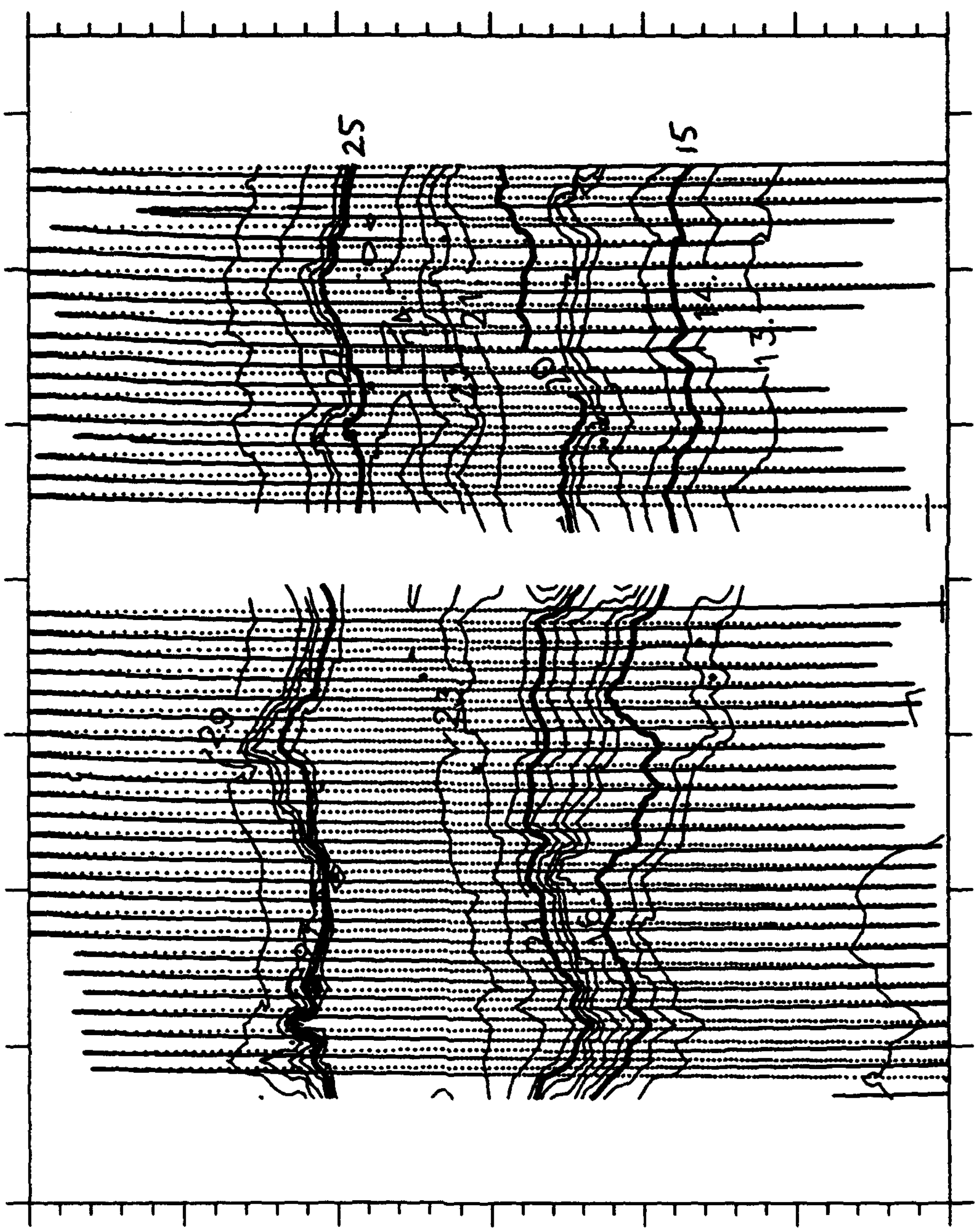
T(°C), E2N, 31 January 1993



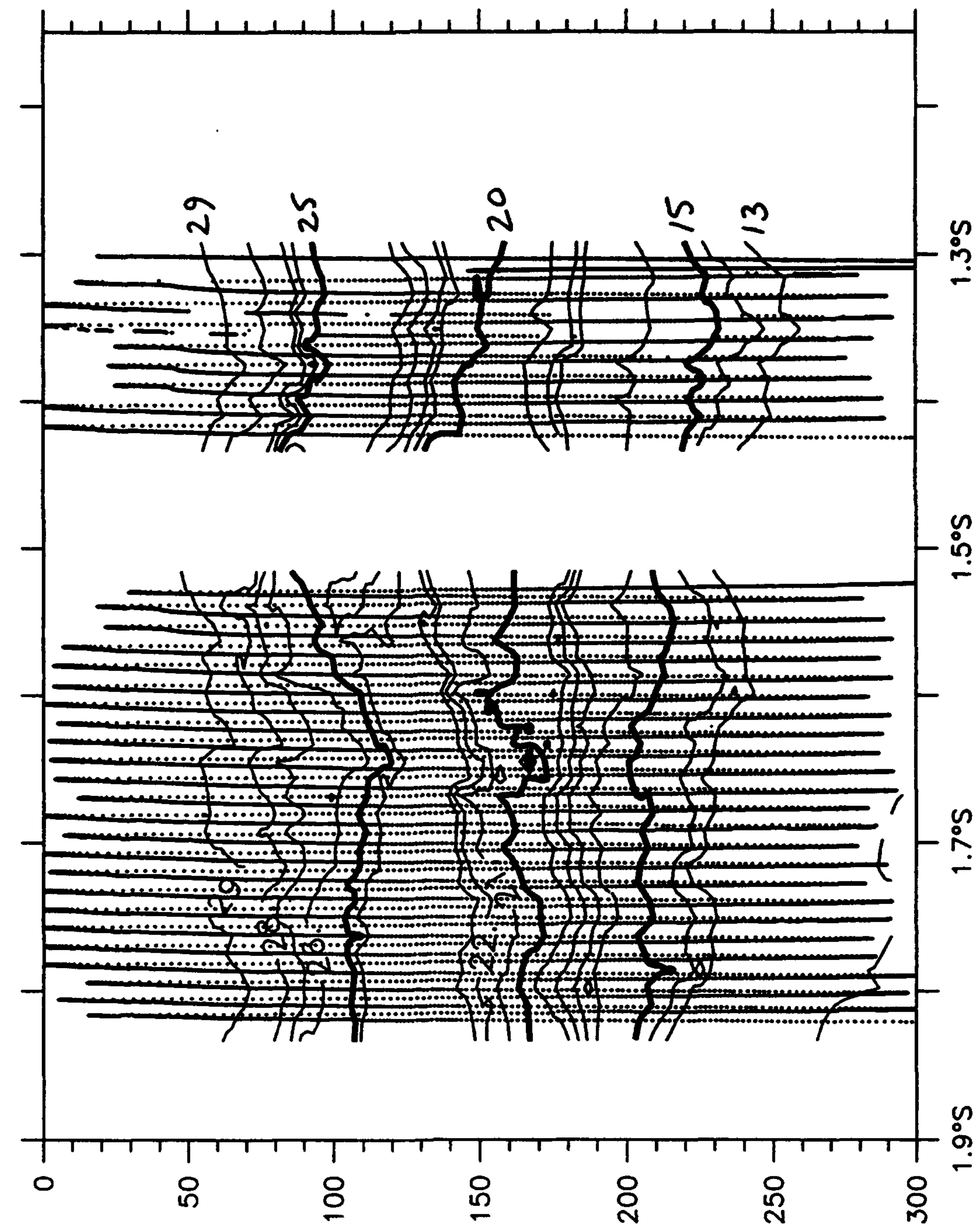
T(°C), E2N, 1 February 1993



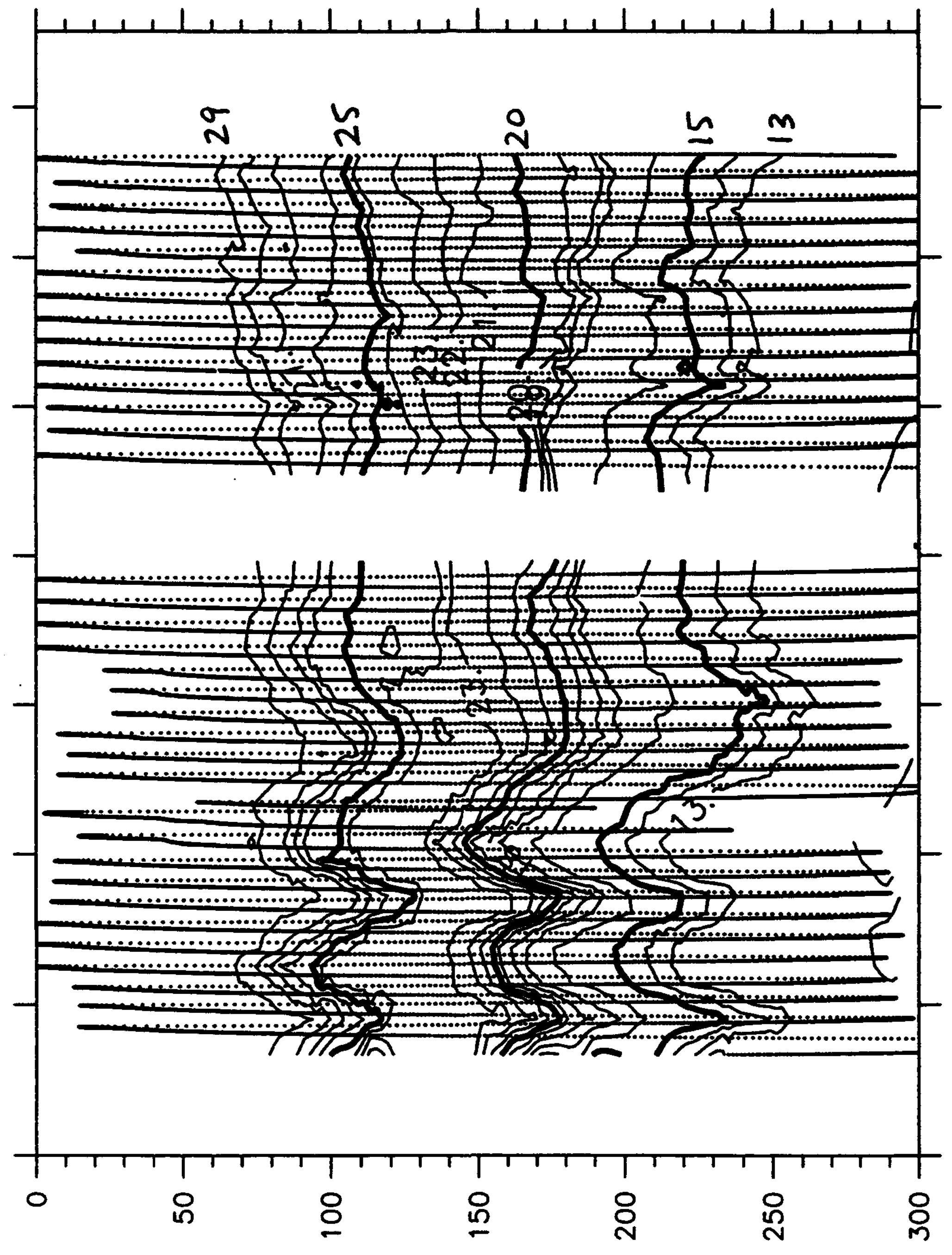
T(°C), E2N, 3 February 1993



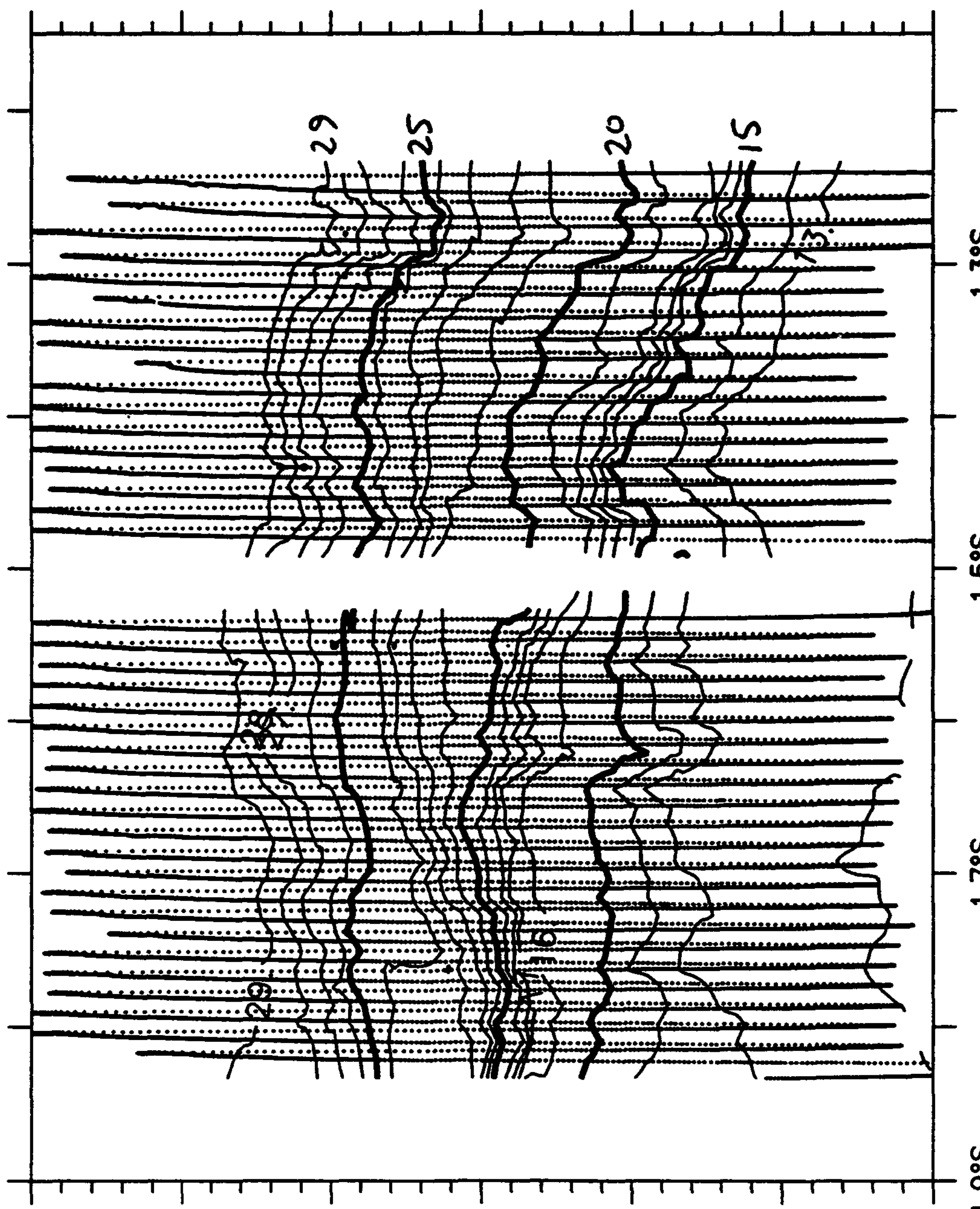
T(°C), E2N, 5 February 1993



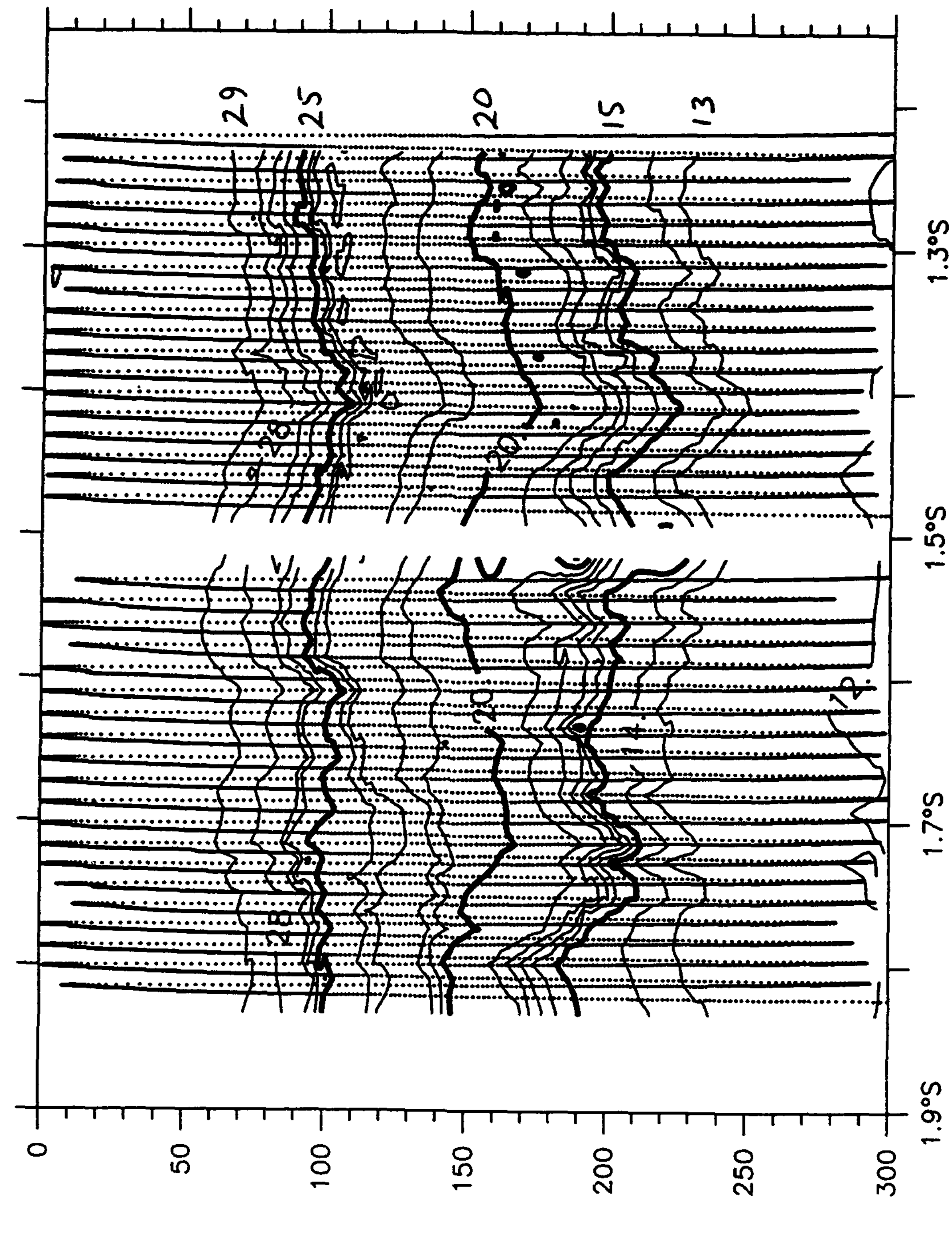
T(°C), E2N, 6 February 1993



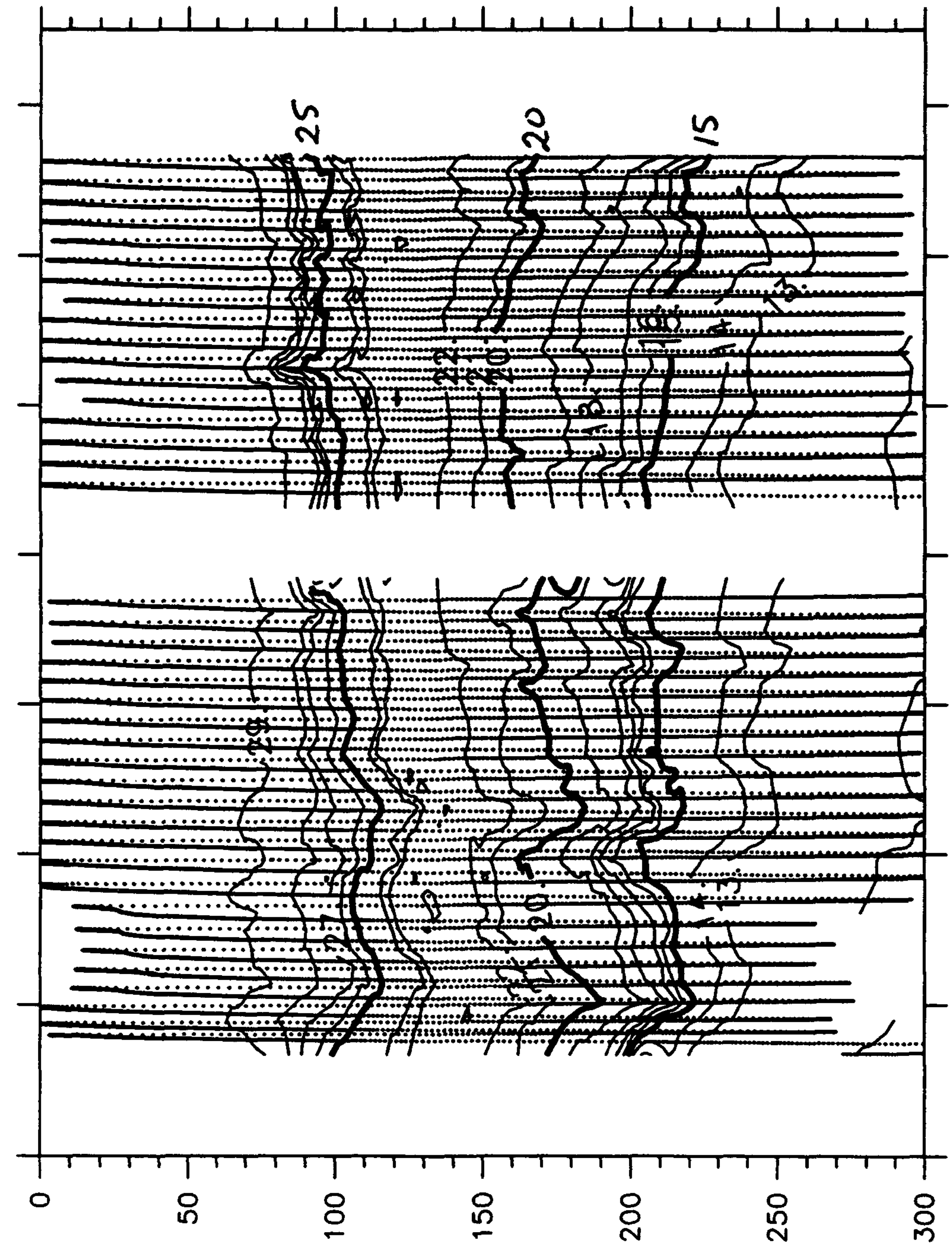
T(°C), E2N, 9 February 1993



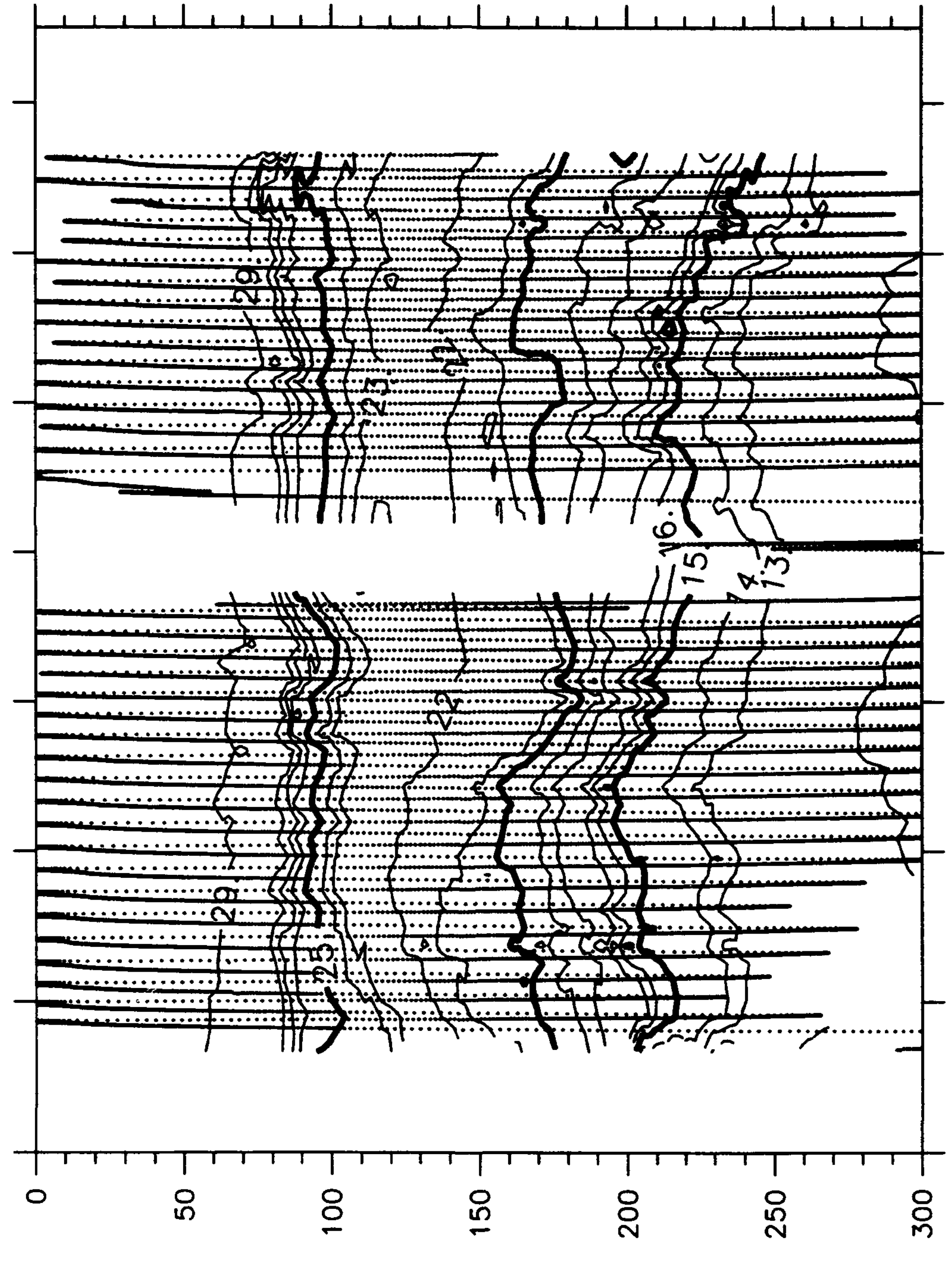
T(°C), E2N, 10 February 1993



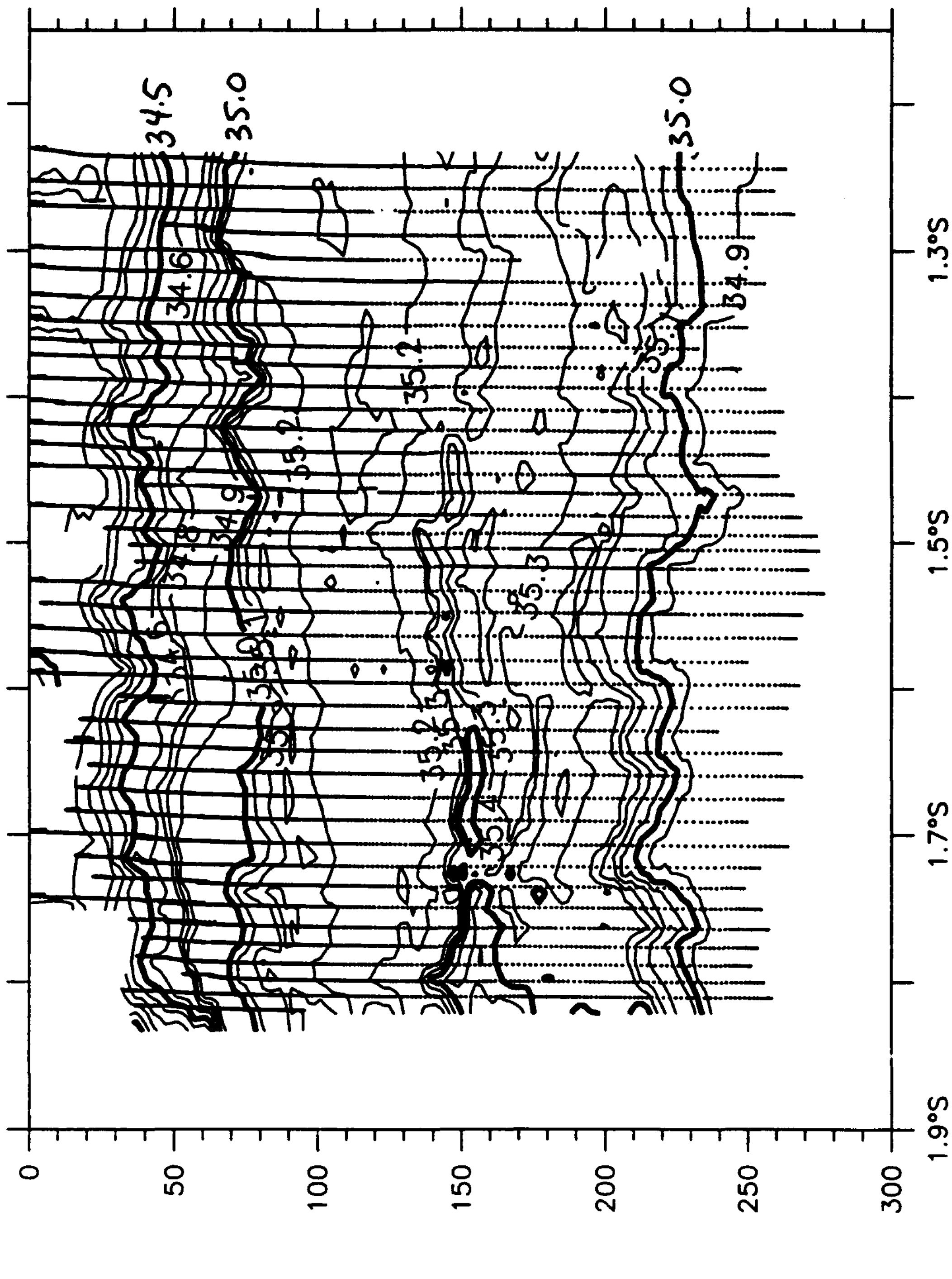
T(°C), E2N, 11 February 1993



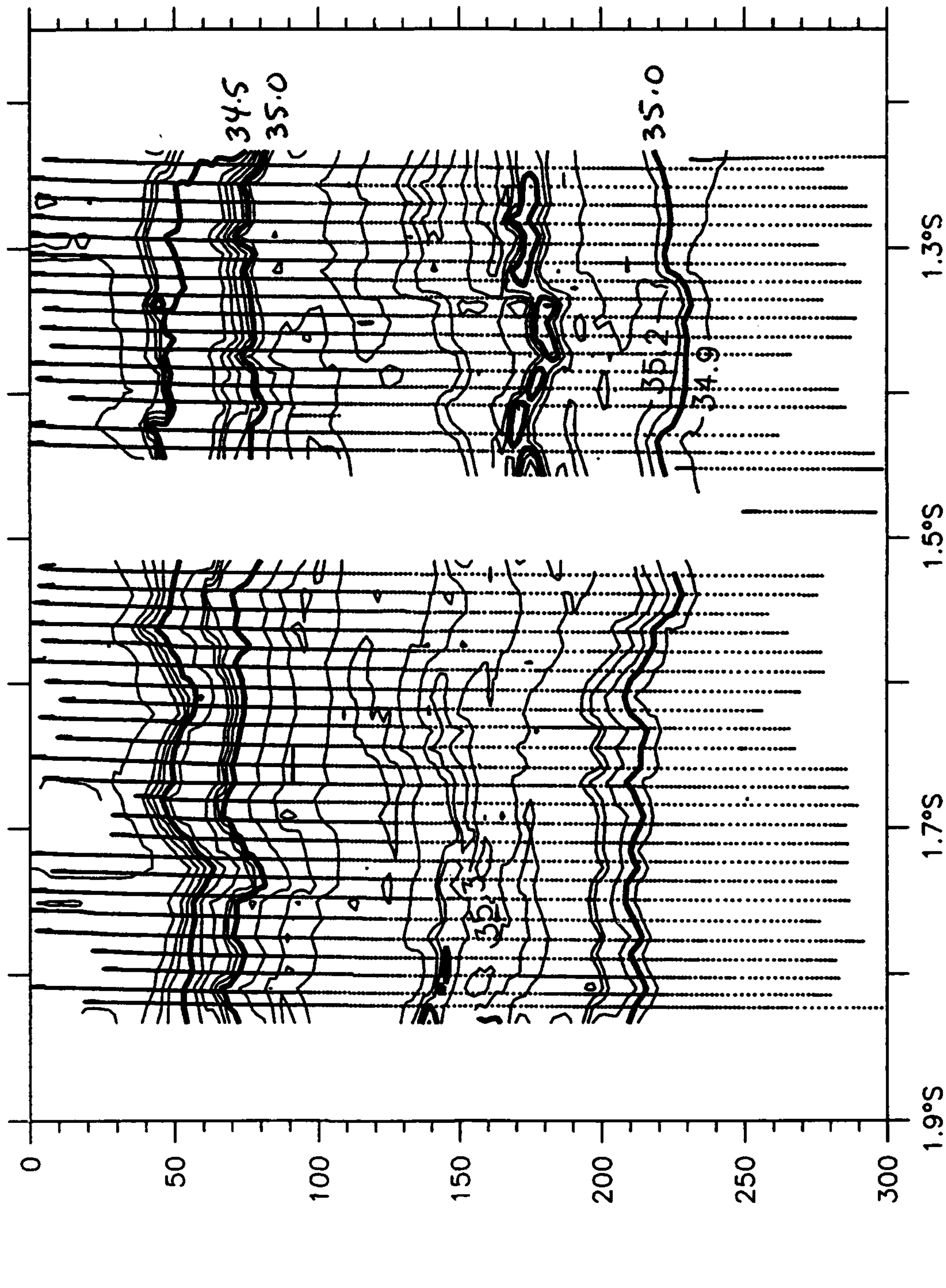
T(°C), E2N, 13 February 1993



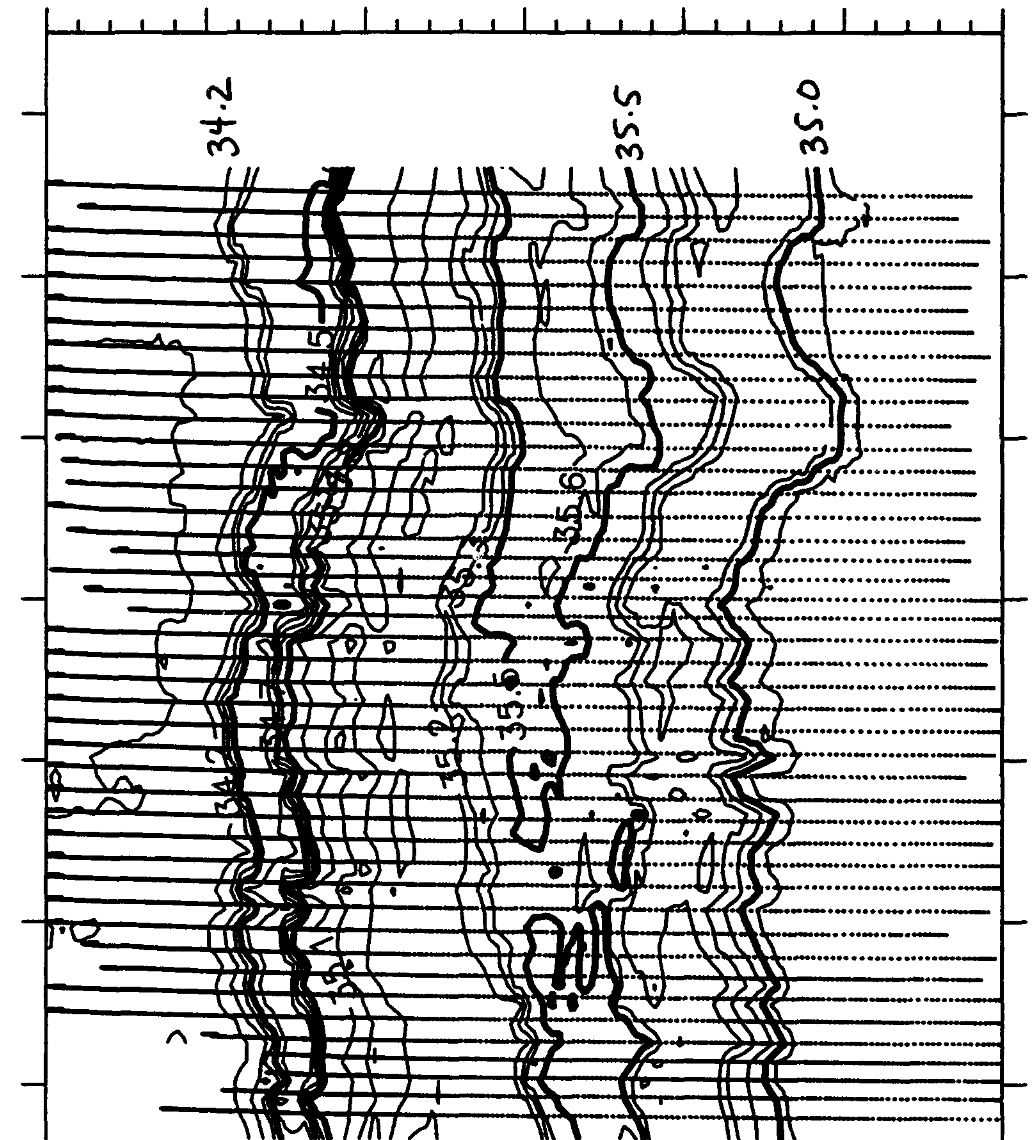
T(°C), E2N, 15 February 1993



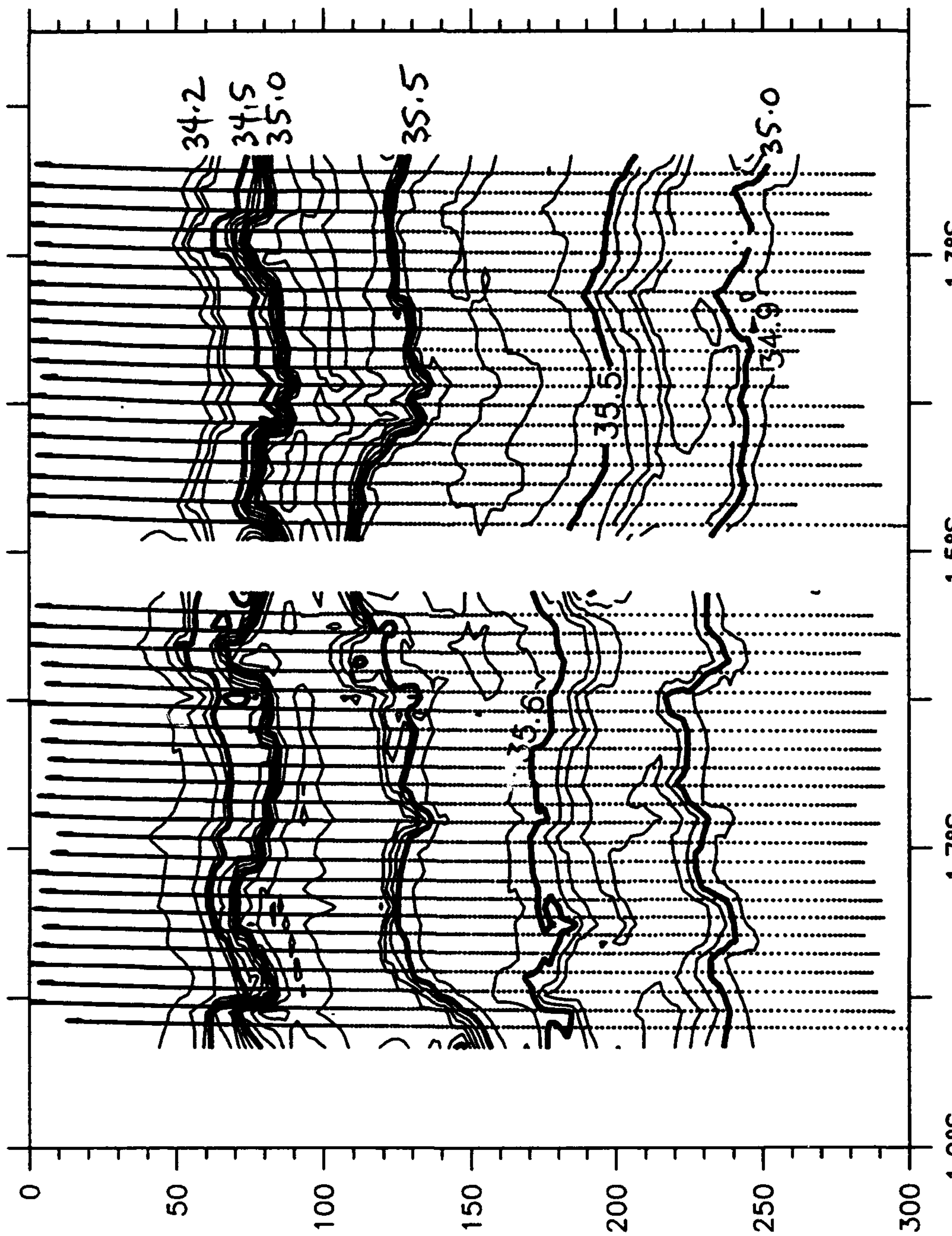
S(psu), E2N, 28 January 1993



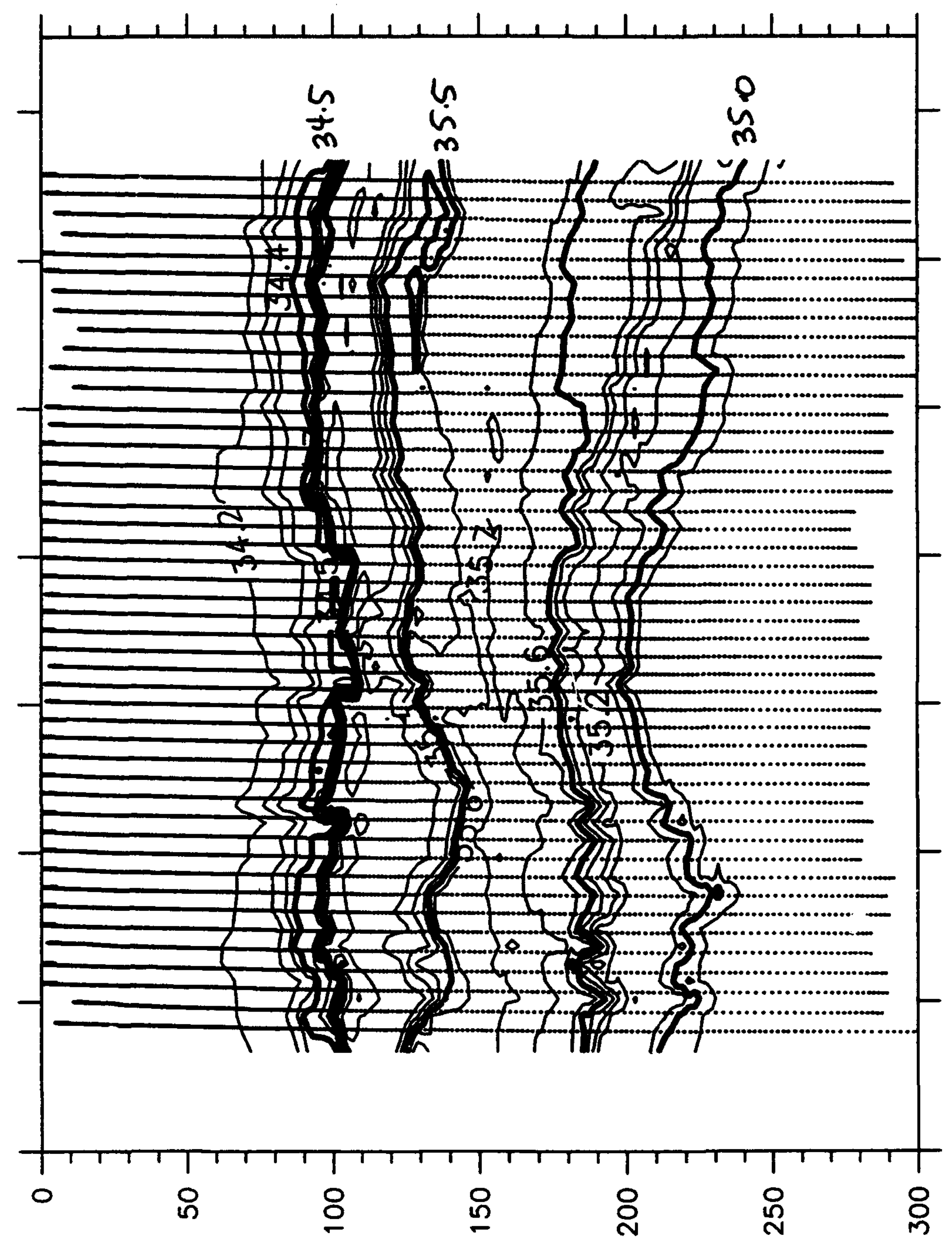
S(psu), E2N, 30 January 1993



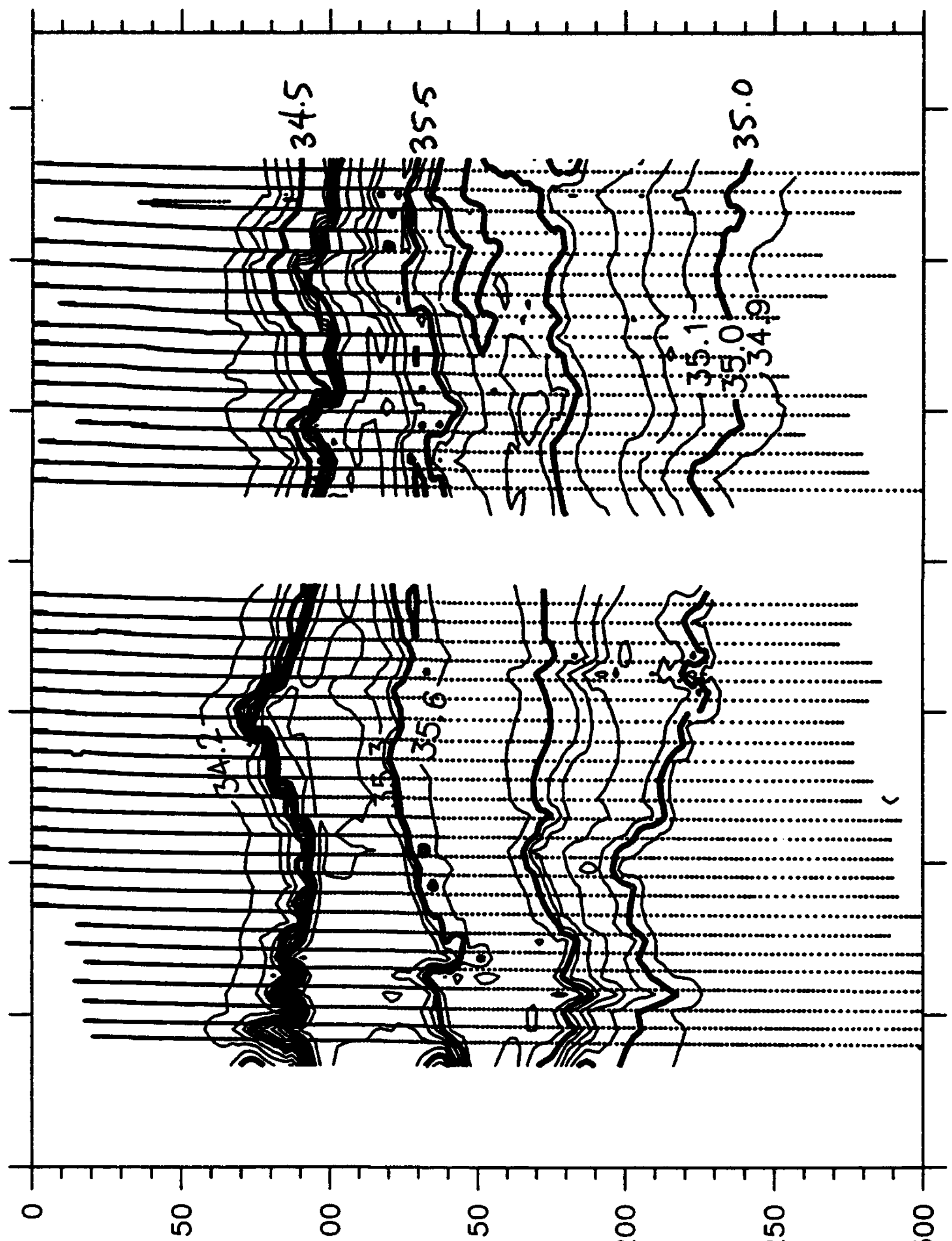
S(psu), E2N, 31 January 1993



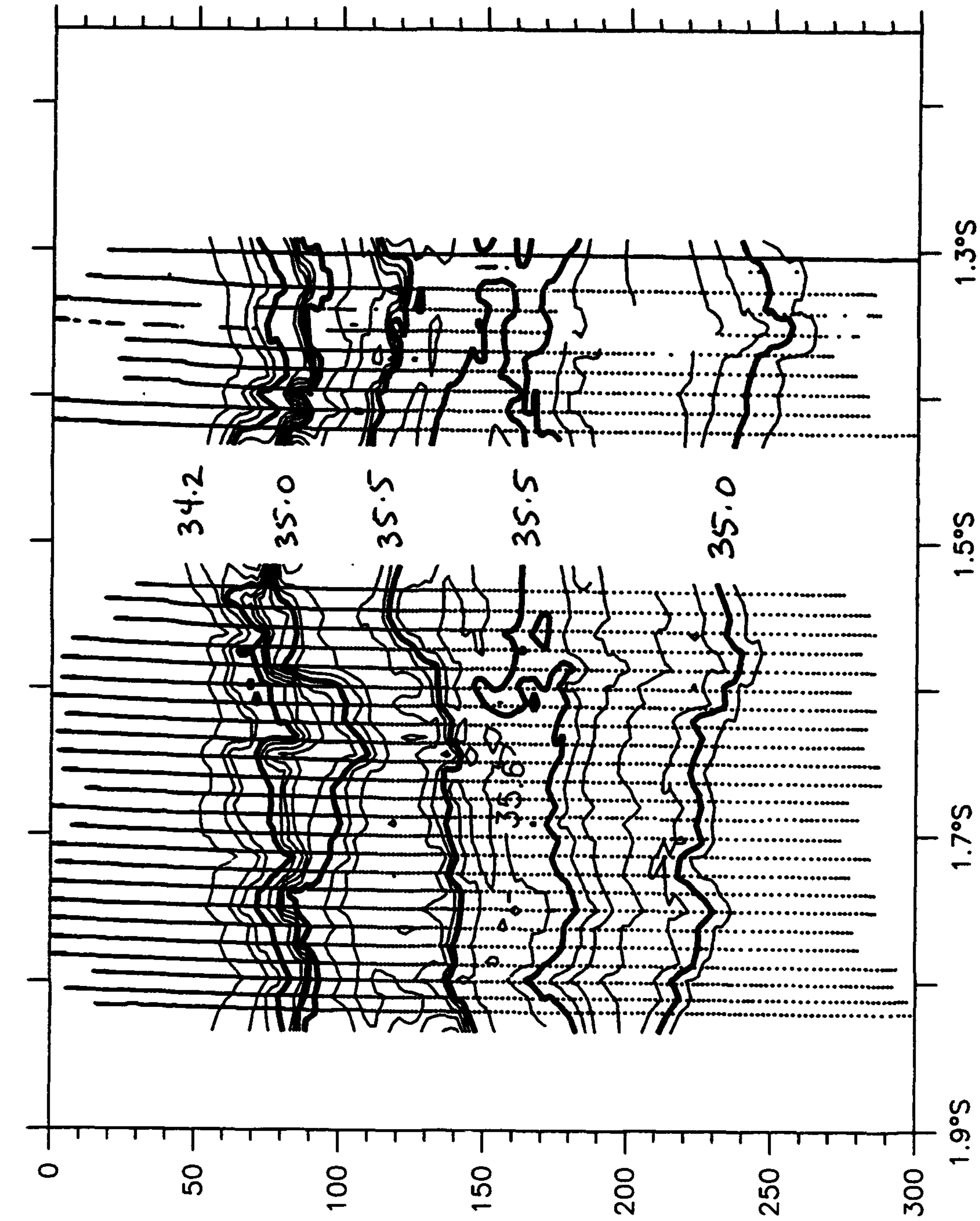
S(psu), E2N, 1 February 1993



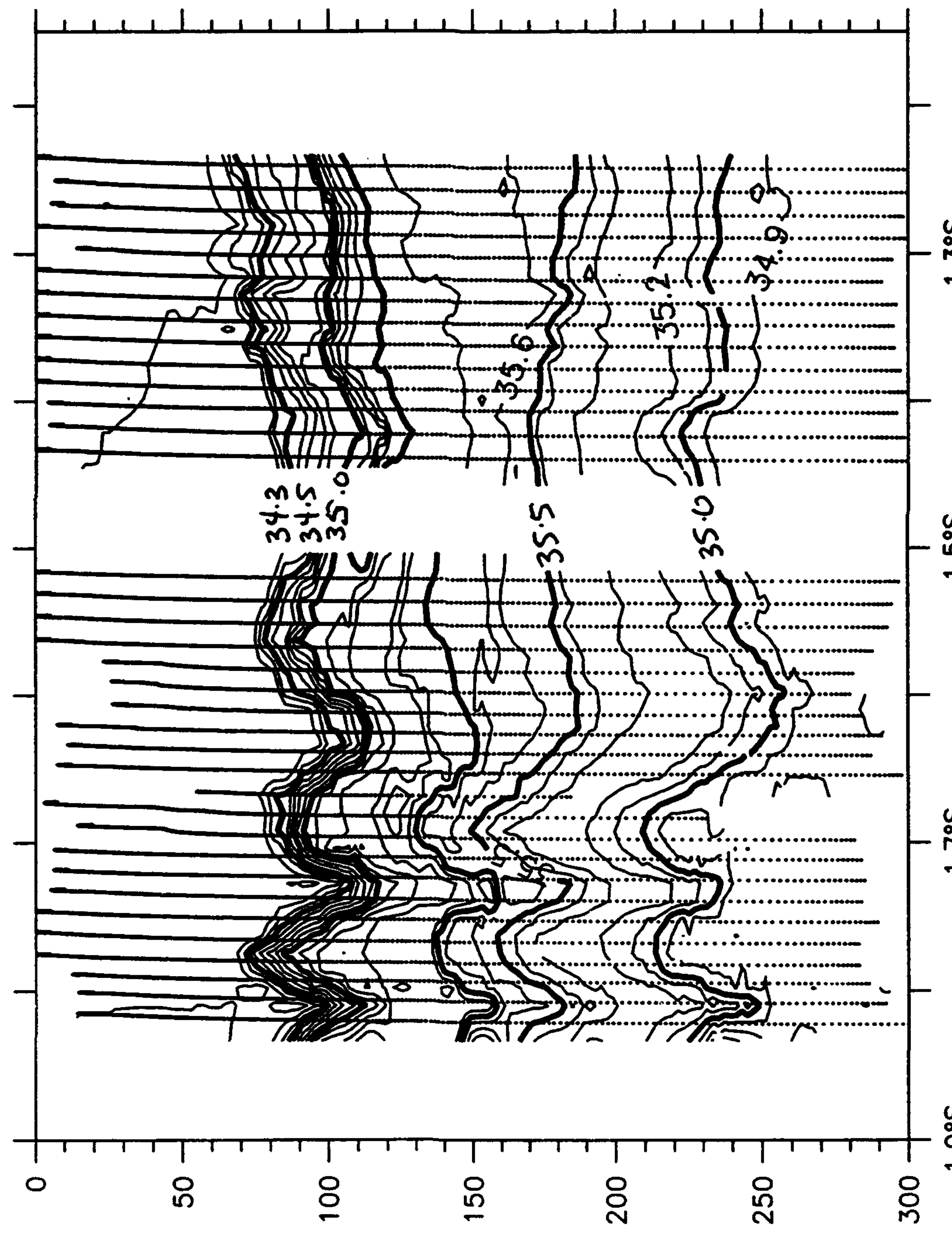
S(psu), E2N, 3 February 1993



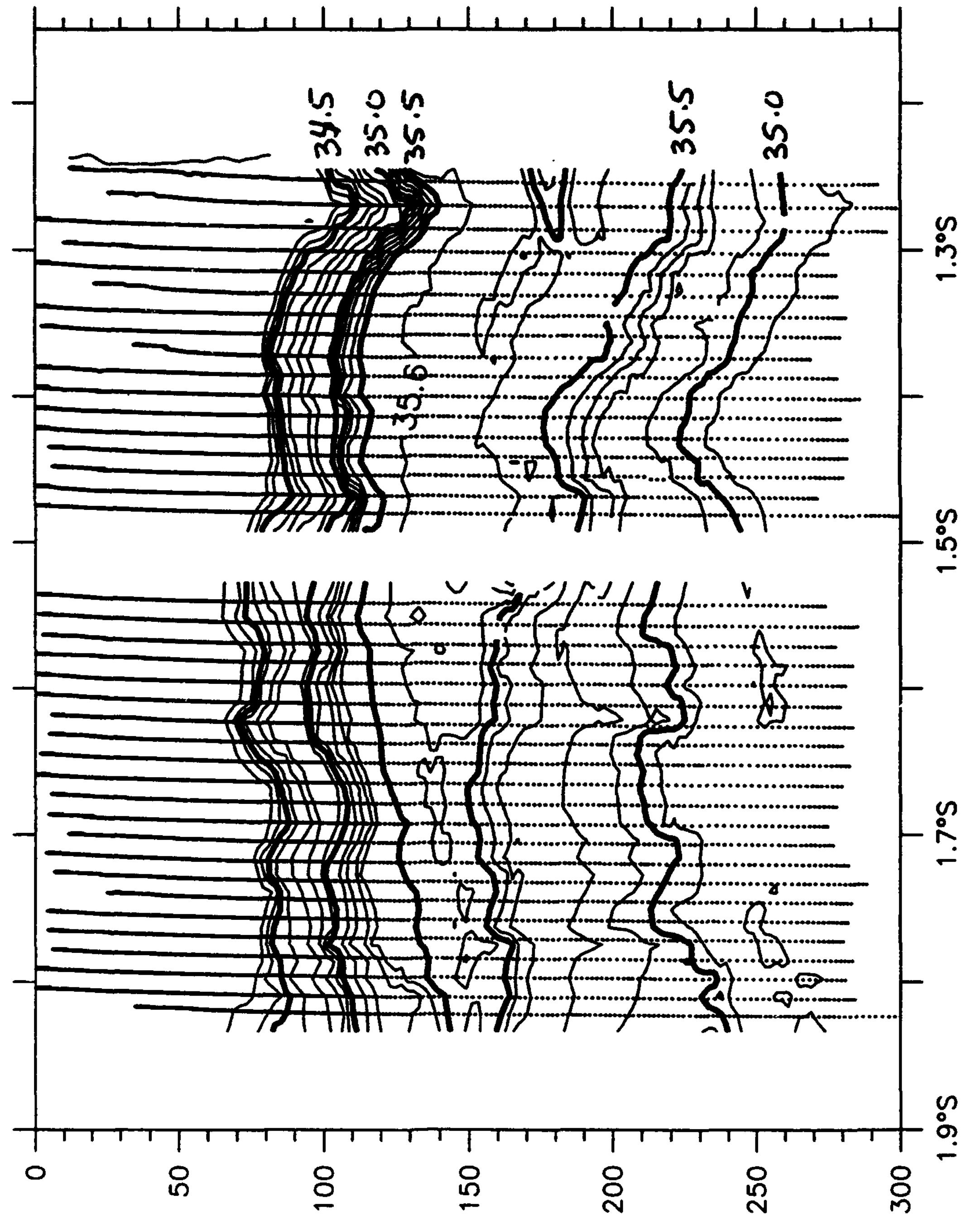
S(psu), E2N, 5 February 1993



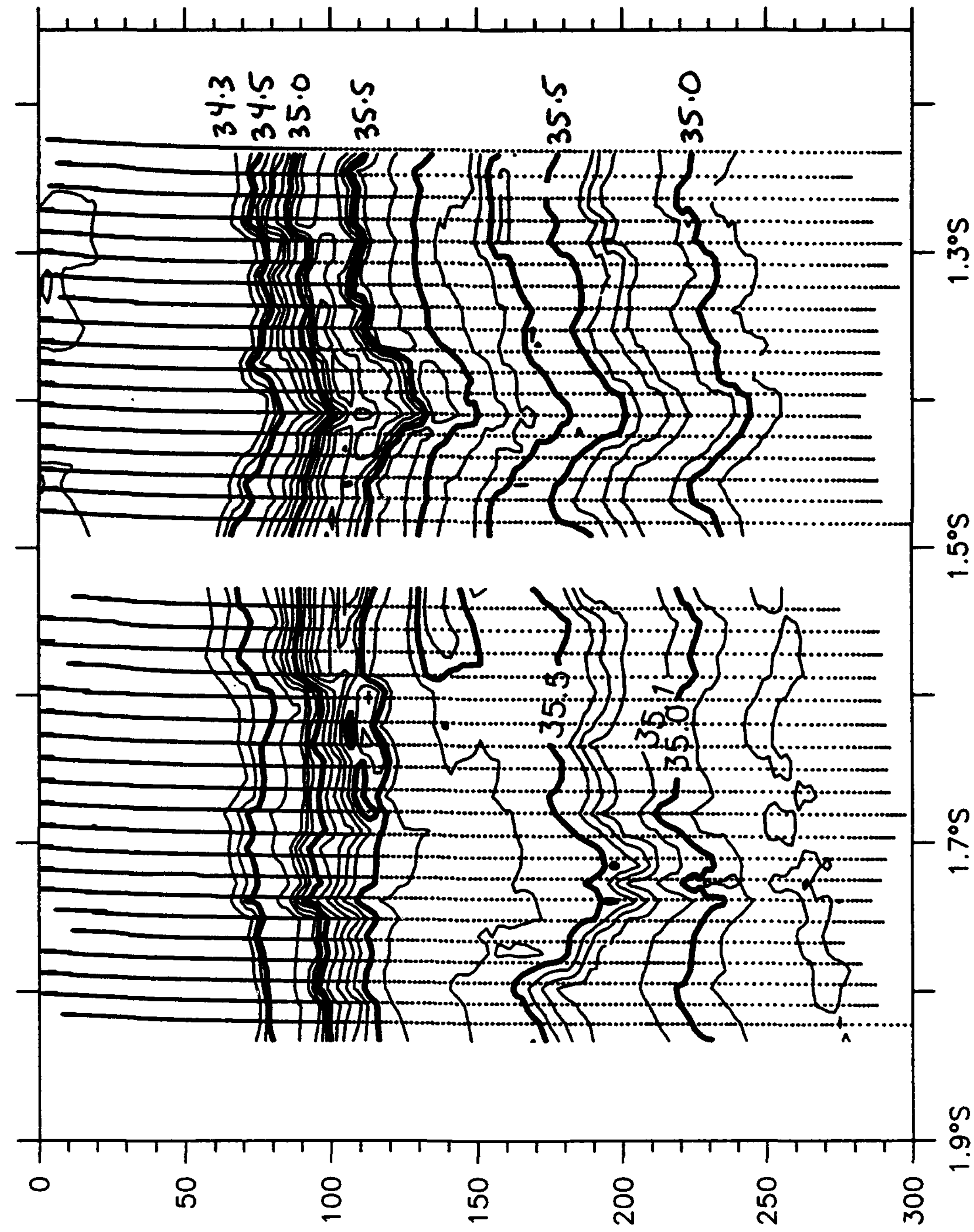
S(psu), E2N, 6 February 1993



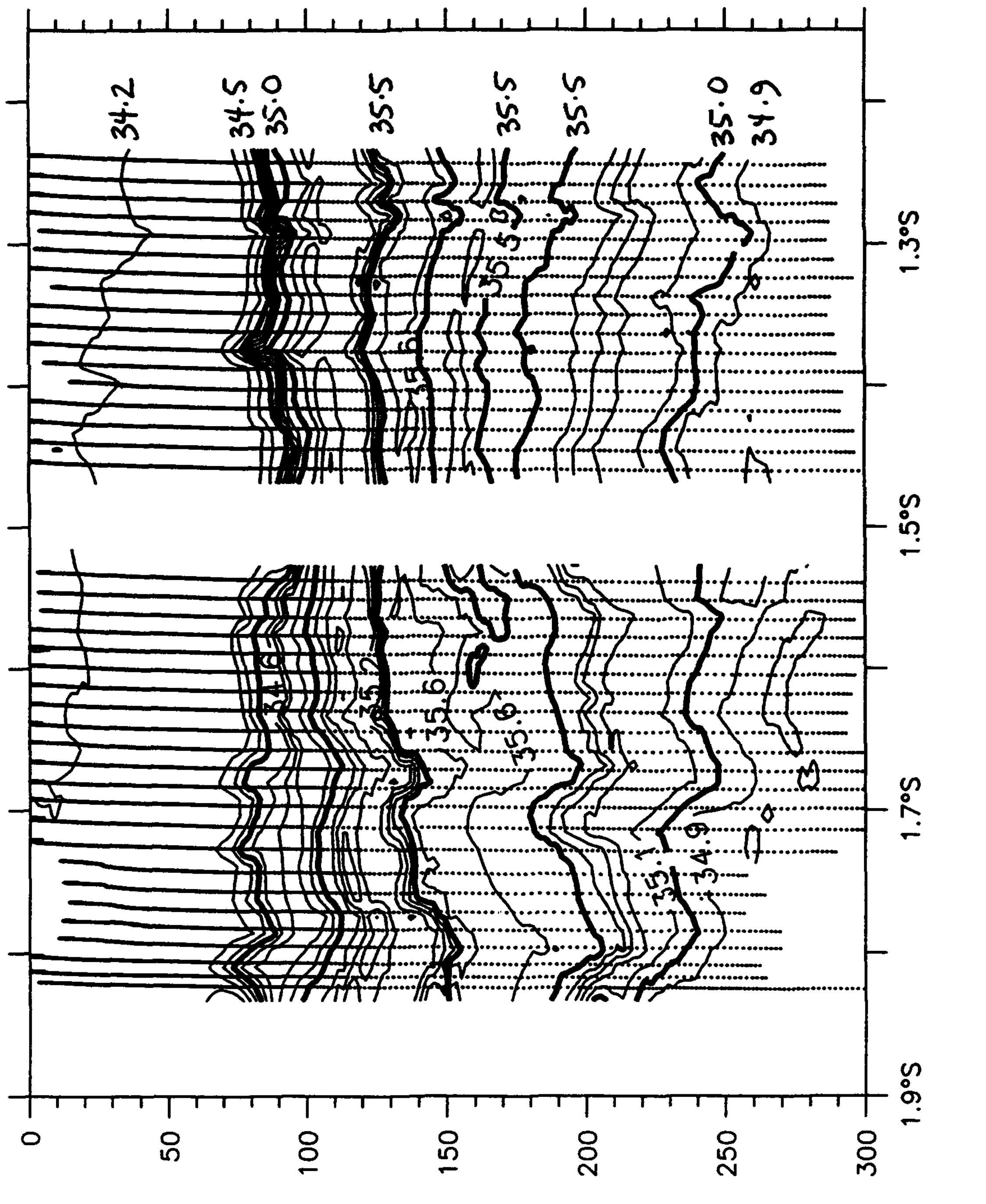
S(psu), E2N, 9 February 1993



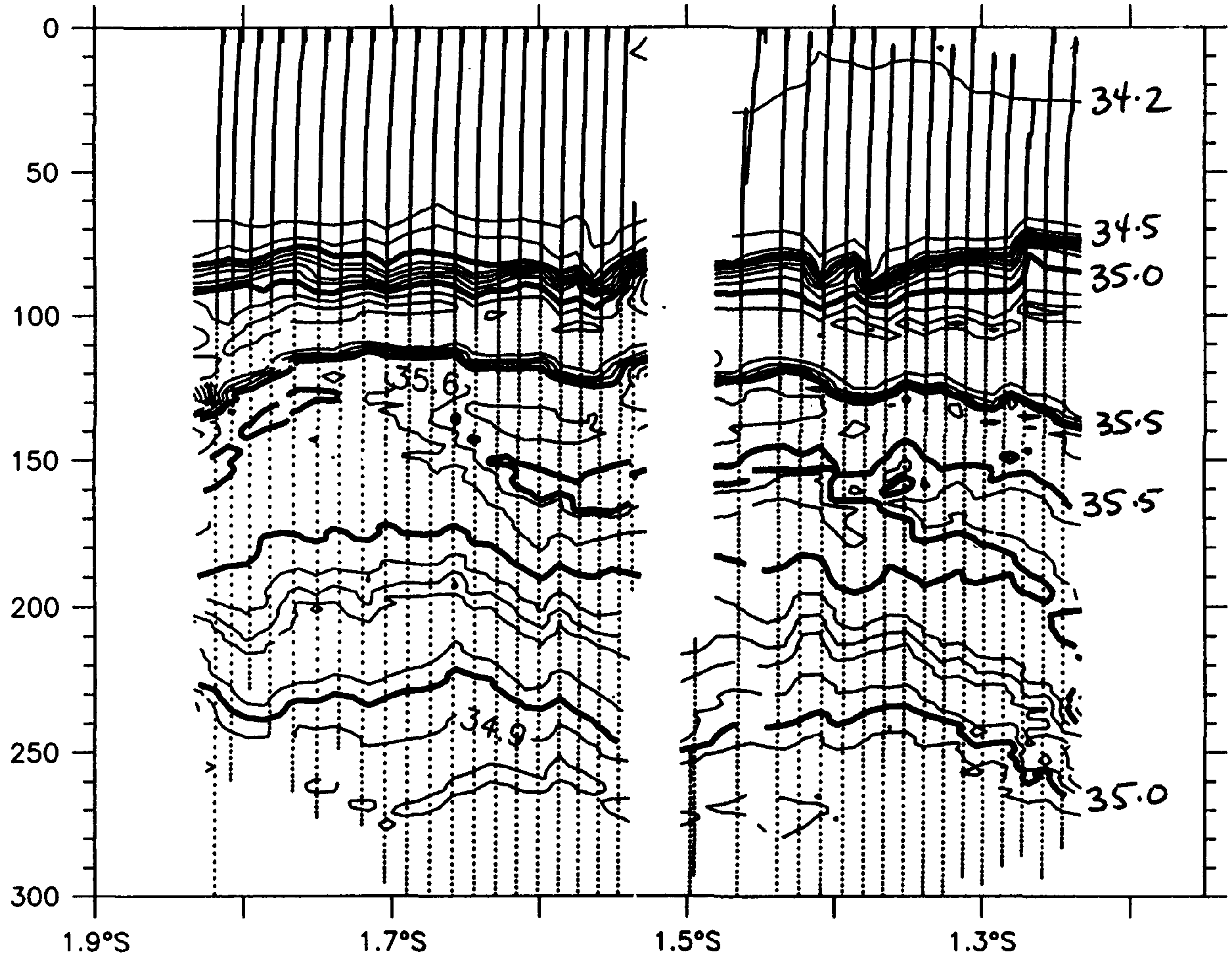
S(psu), E2N, 10 February 1993



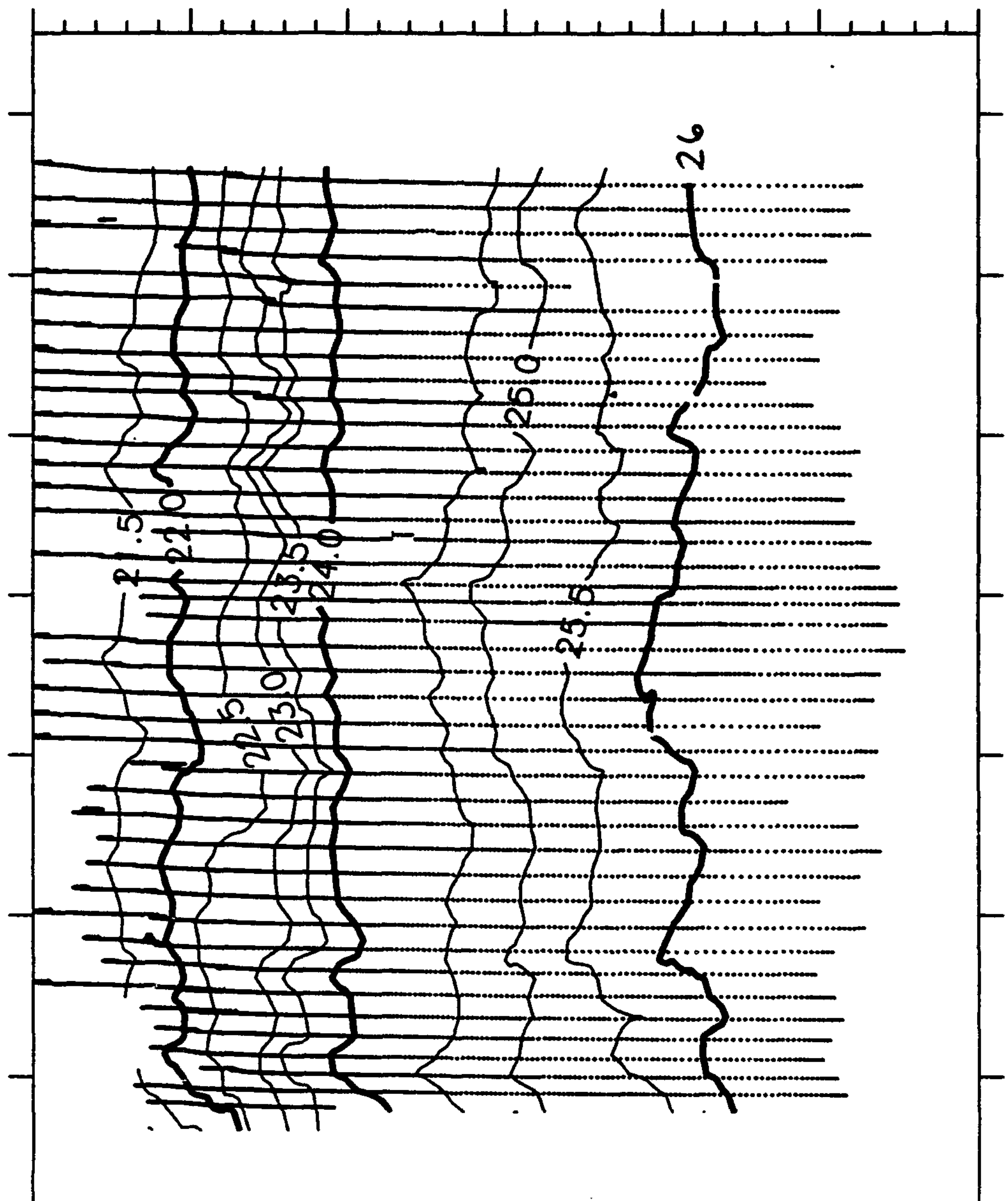
S(psu), E2N, 11 February 1993



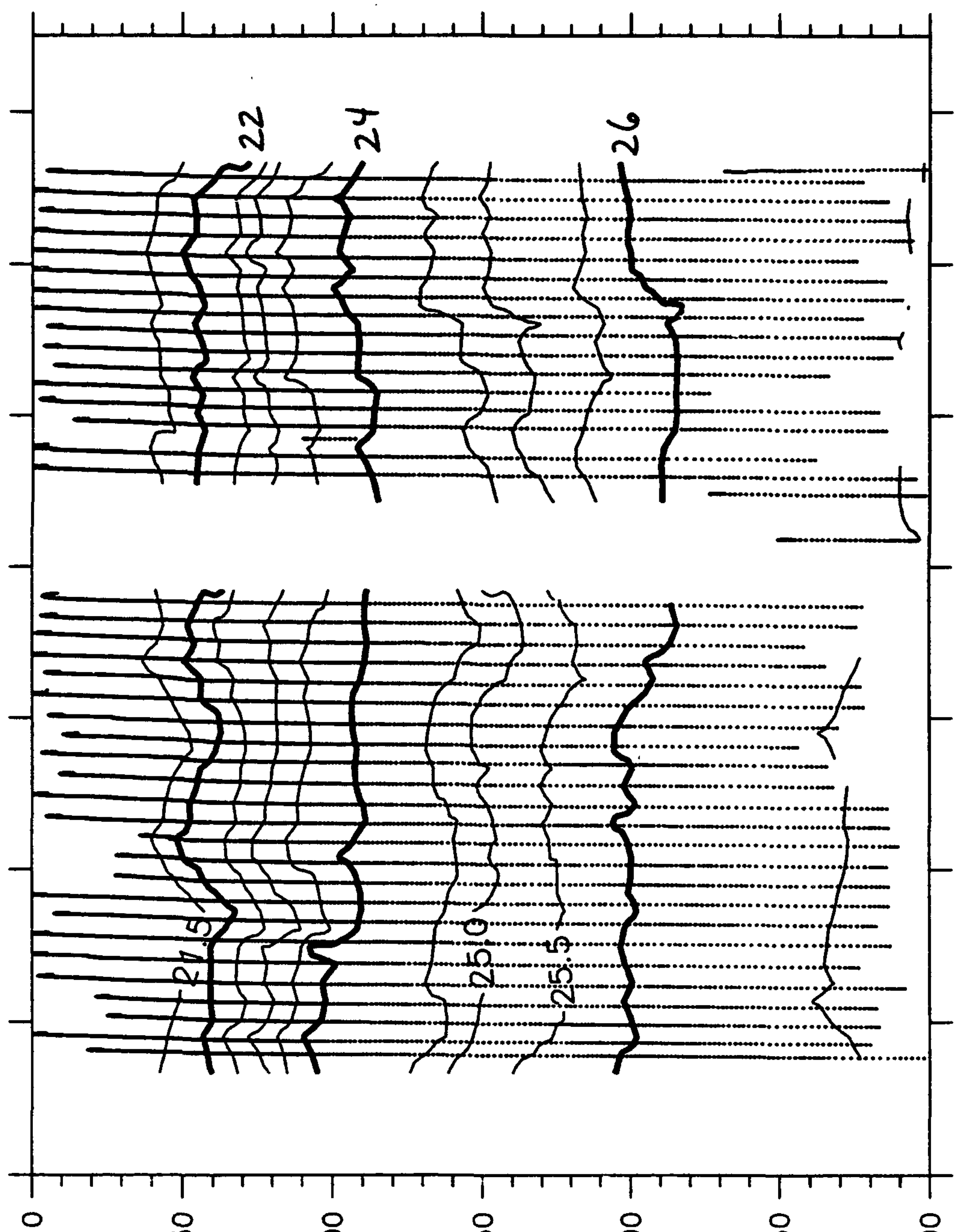
S(psu), E2N, 13 February 1993



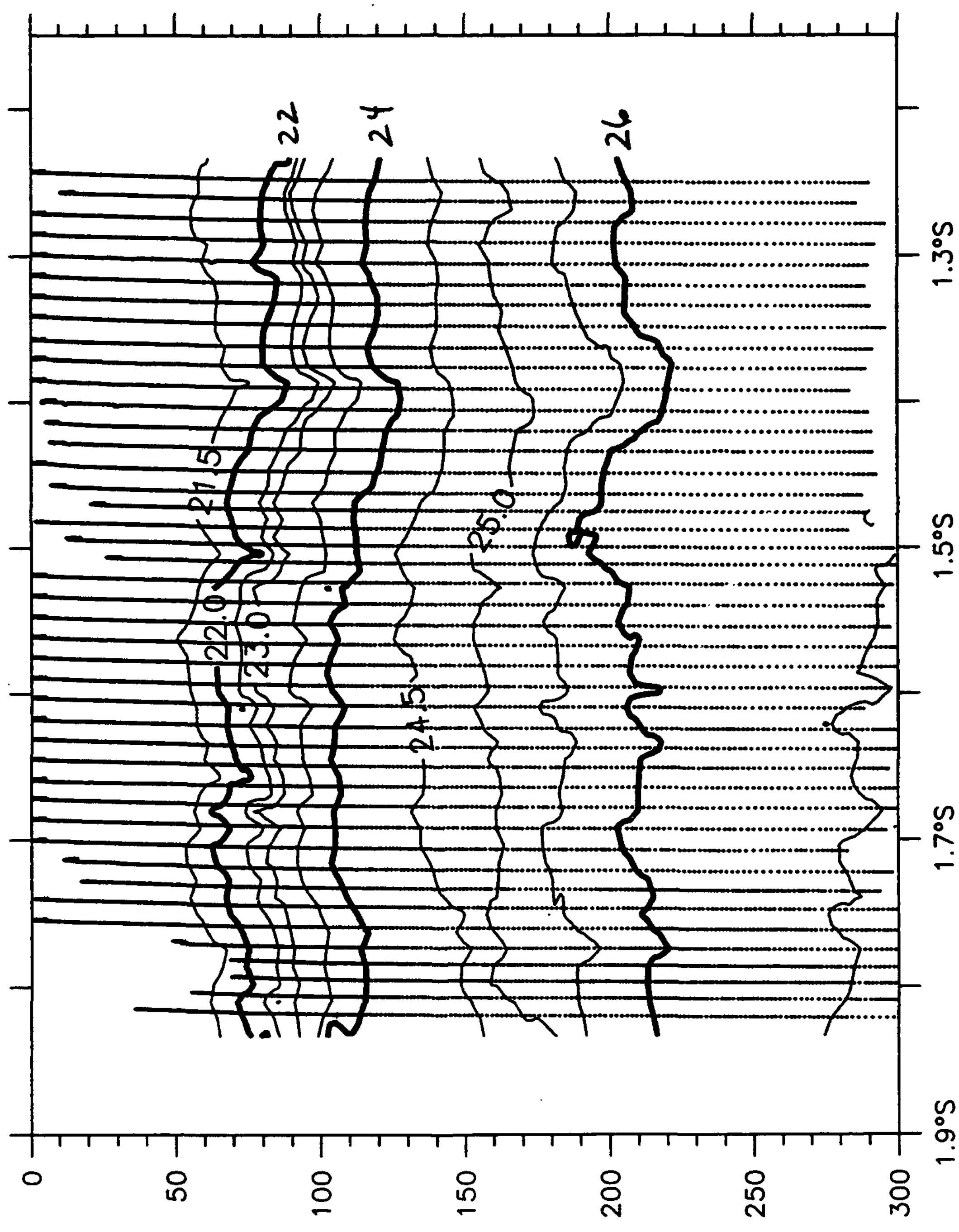
S(psu), E2N, 15 February 1993



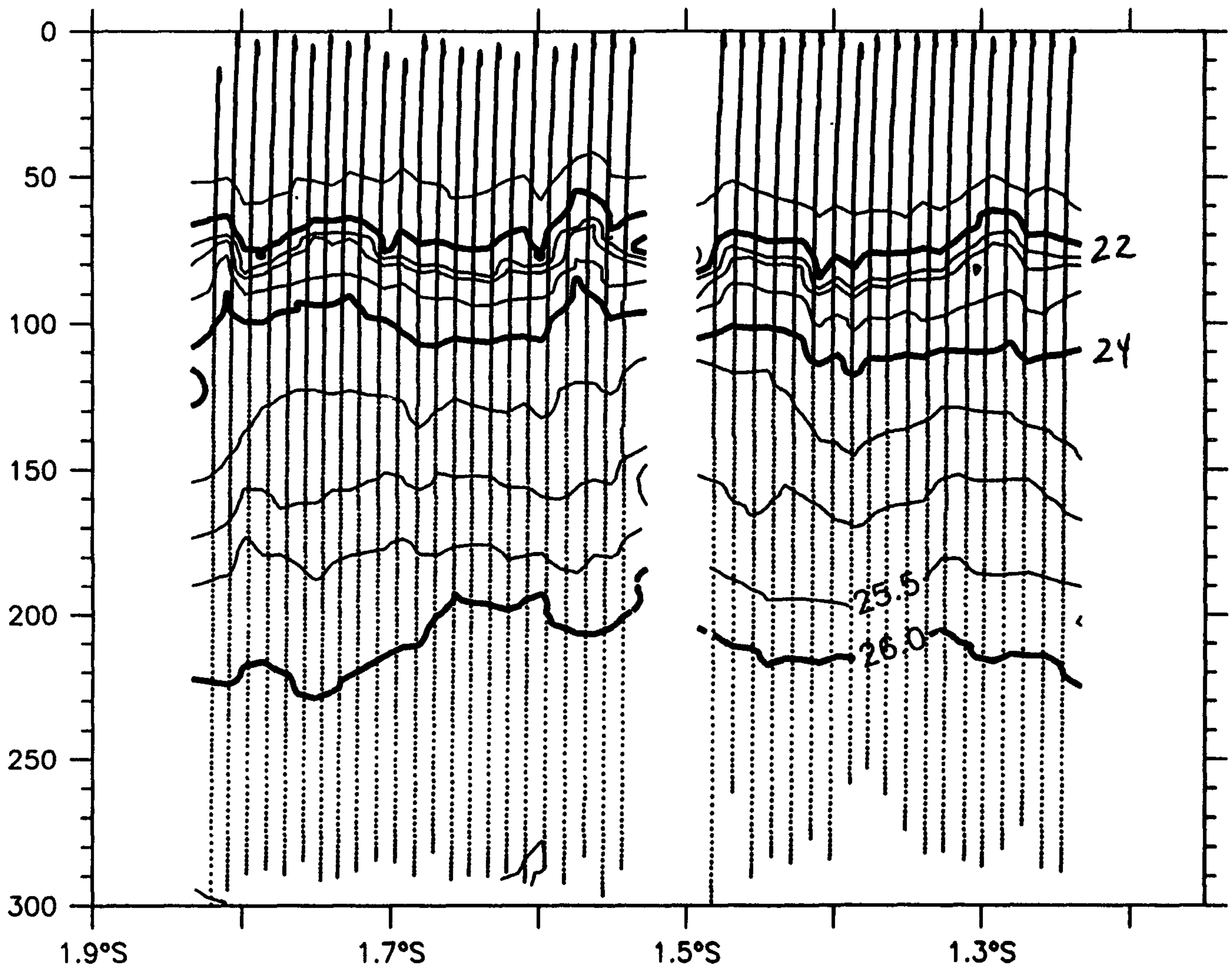
Sigma–t, E2N, 28 January 1993



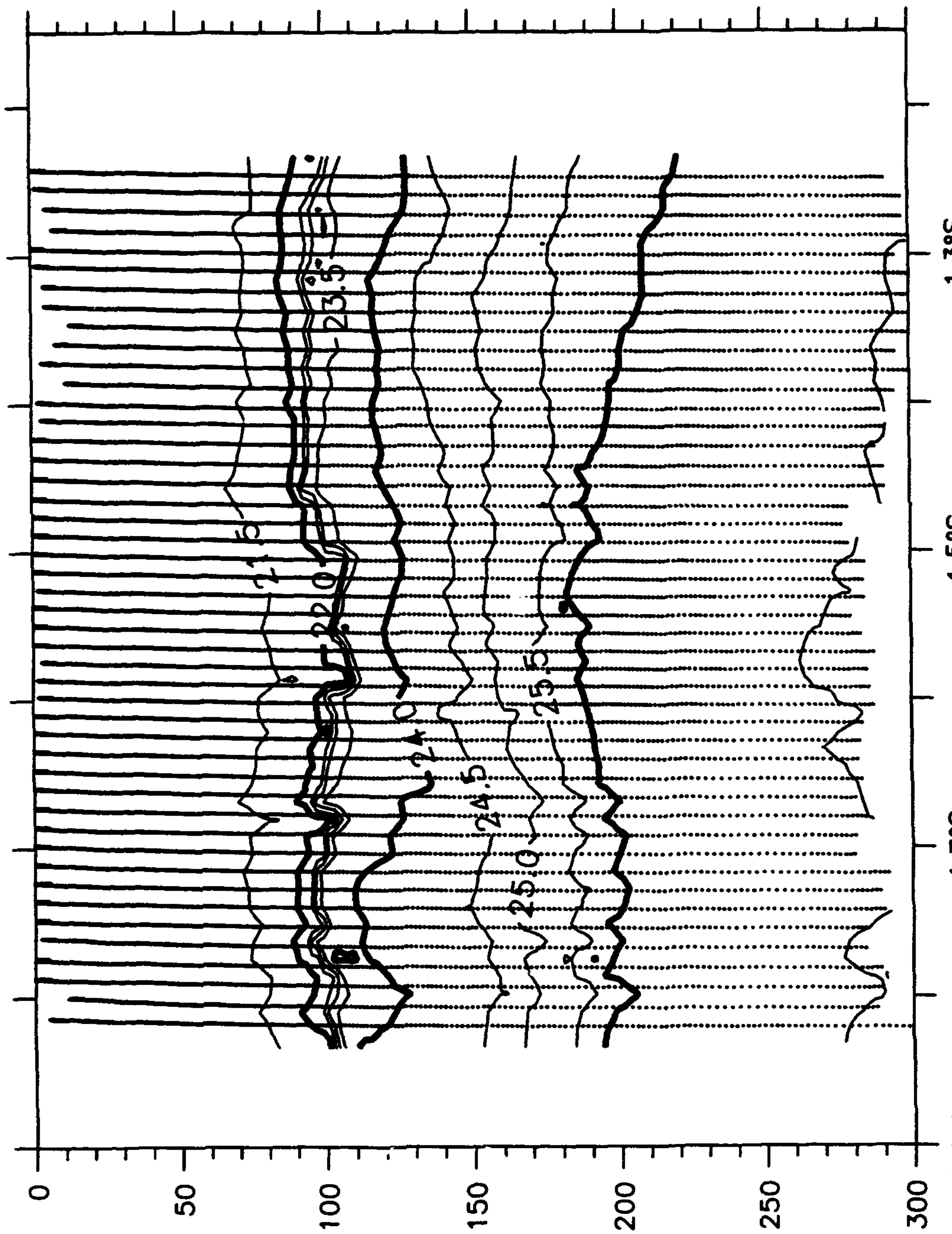
Sigma-t, E2N, 30 January 1993



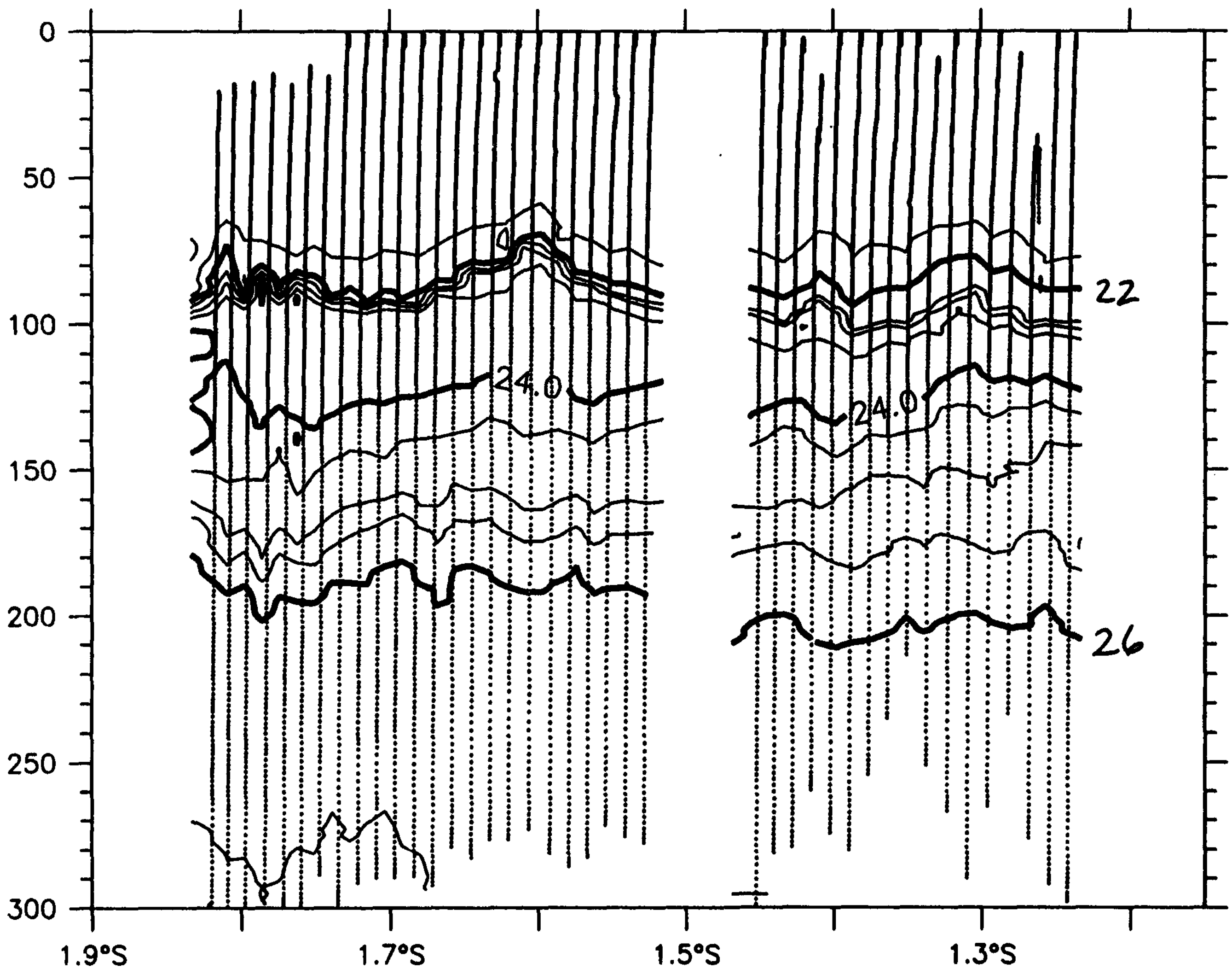
Sigma–t, E2N, 31 January 1993



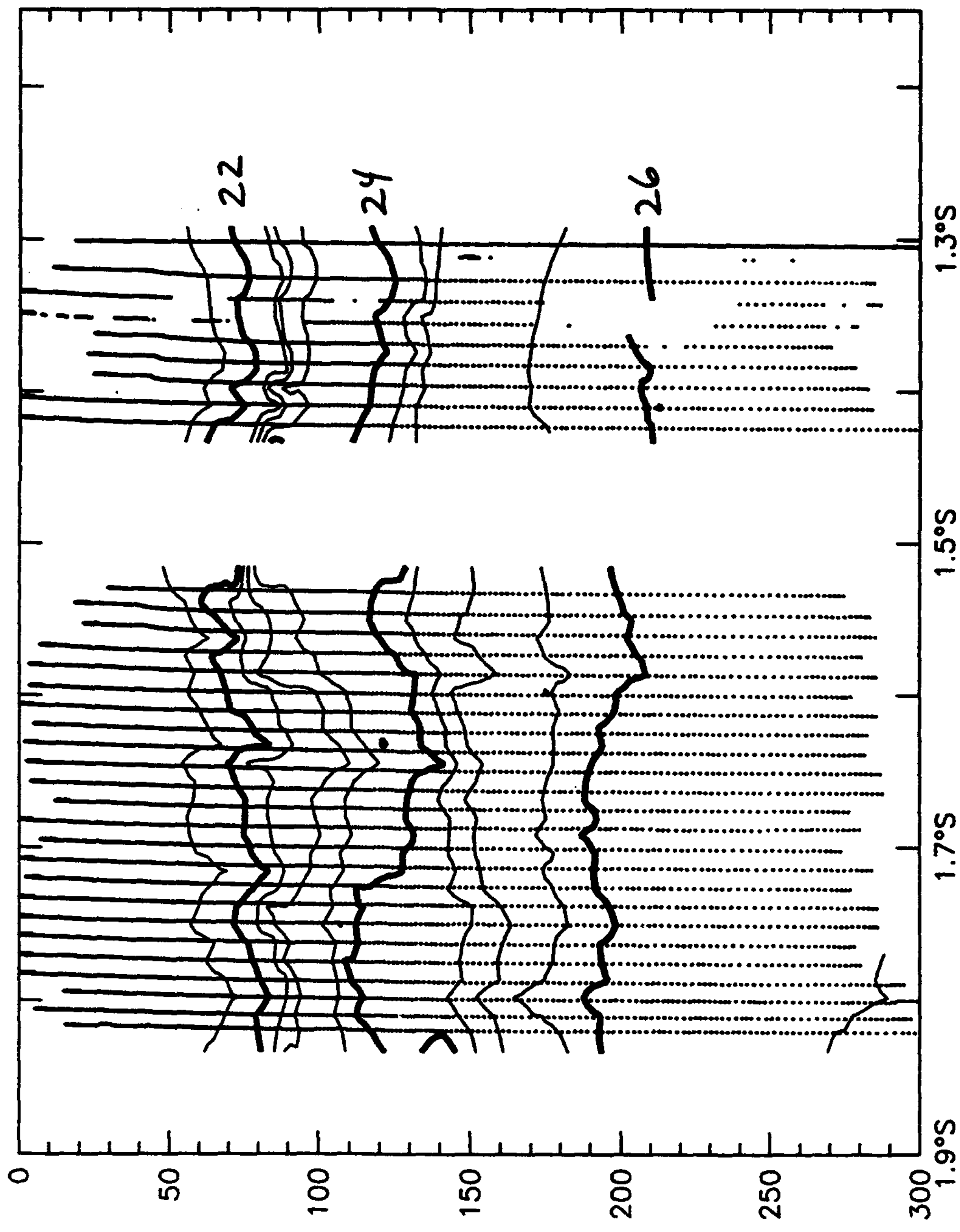
Sigma–t, E2N, 1 February 1993



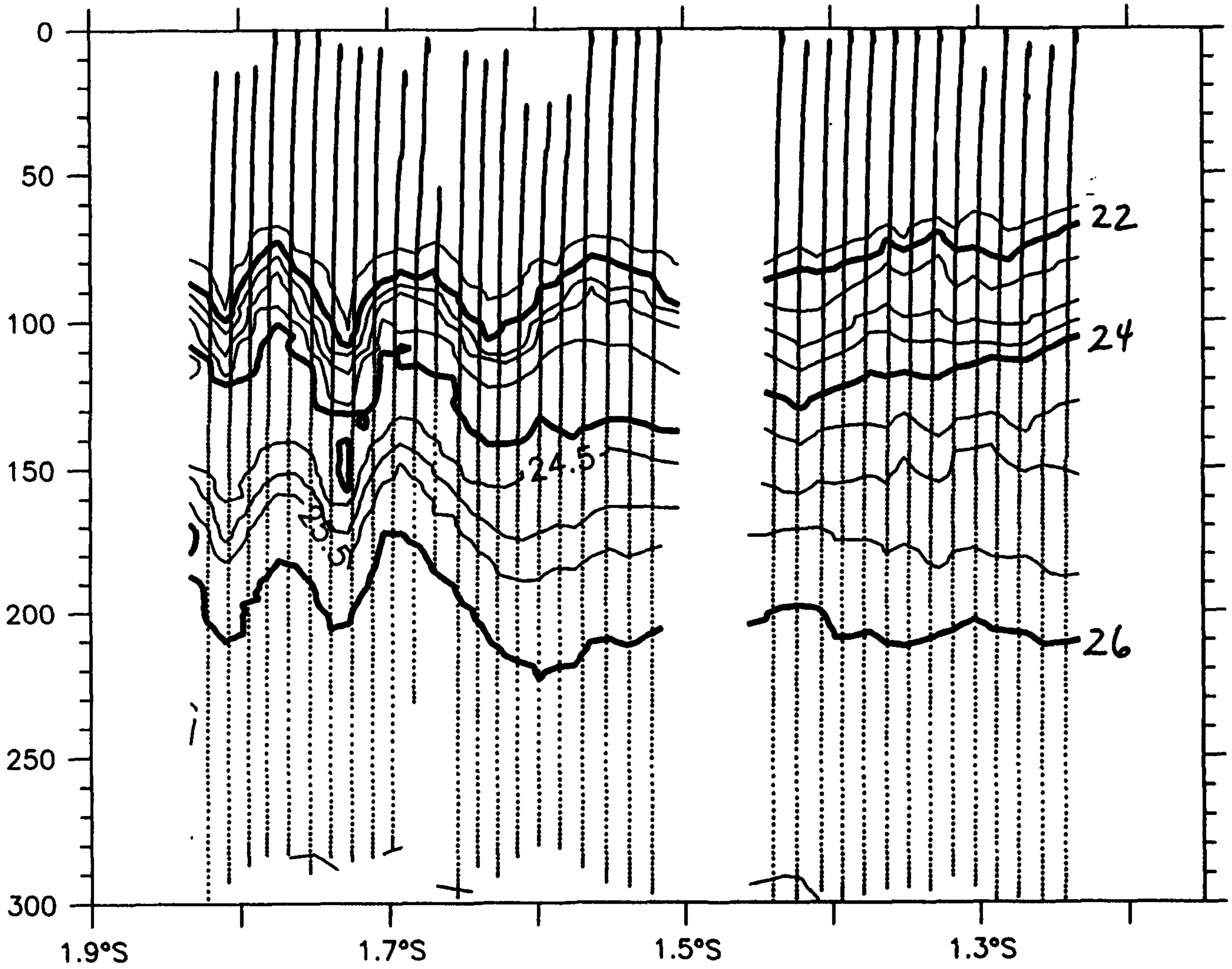
Sigma–t, E2N, 3 February 1993



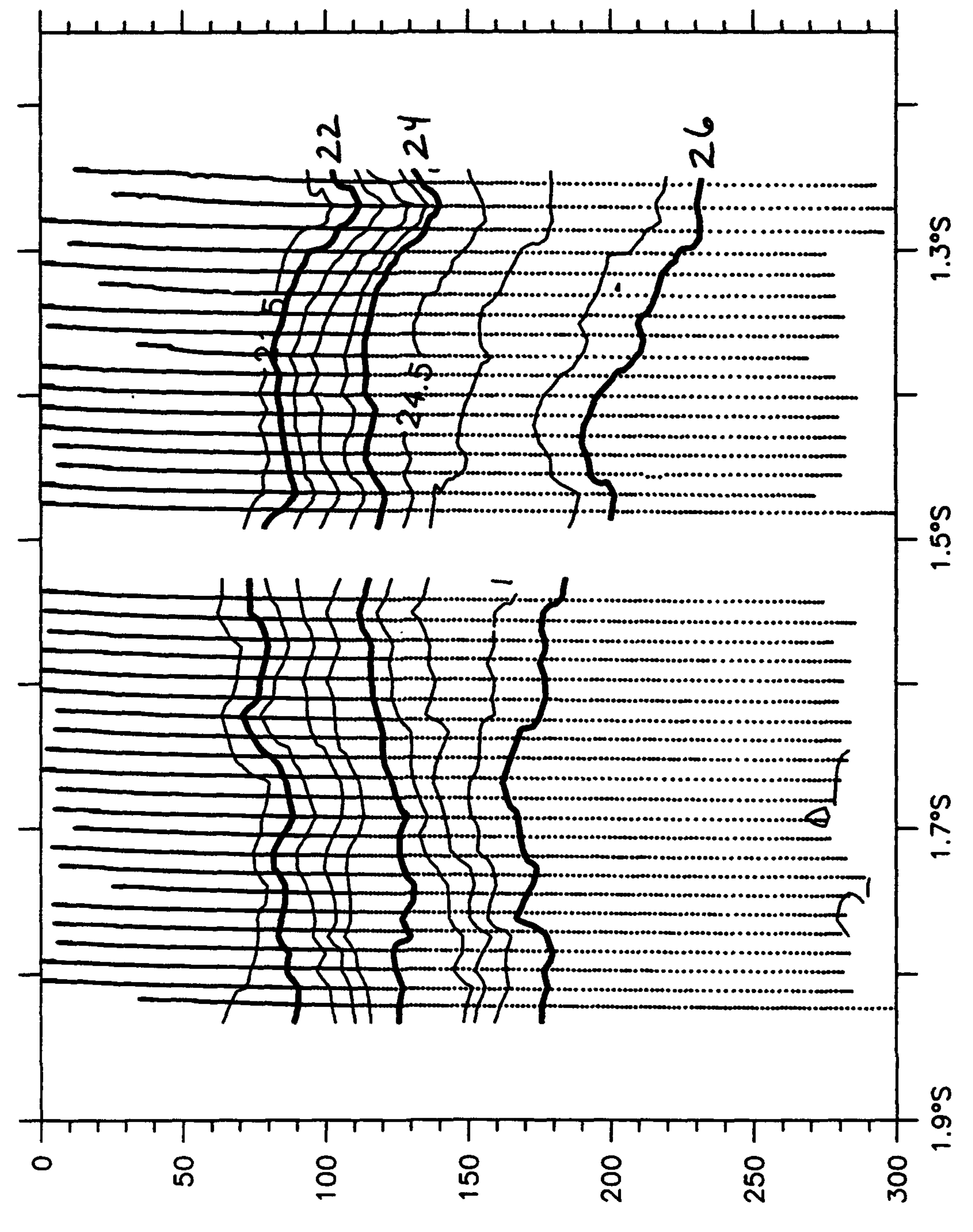
Sigma−t, E2N, 5 February 1993



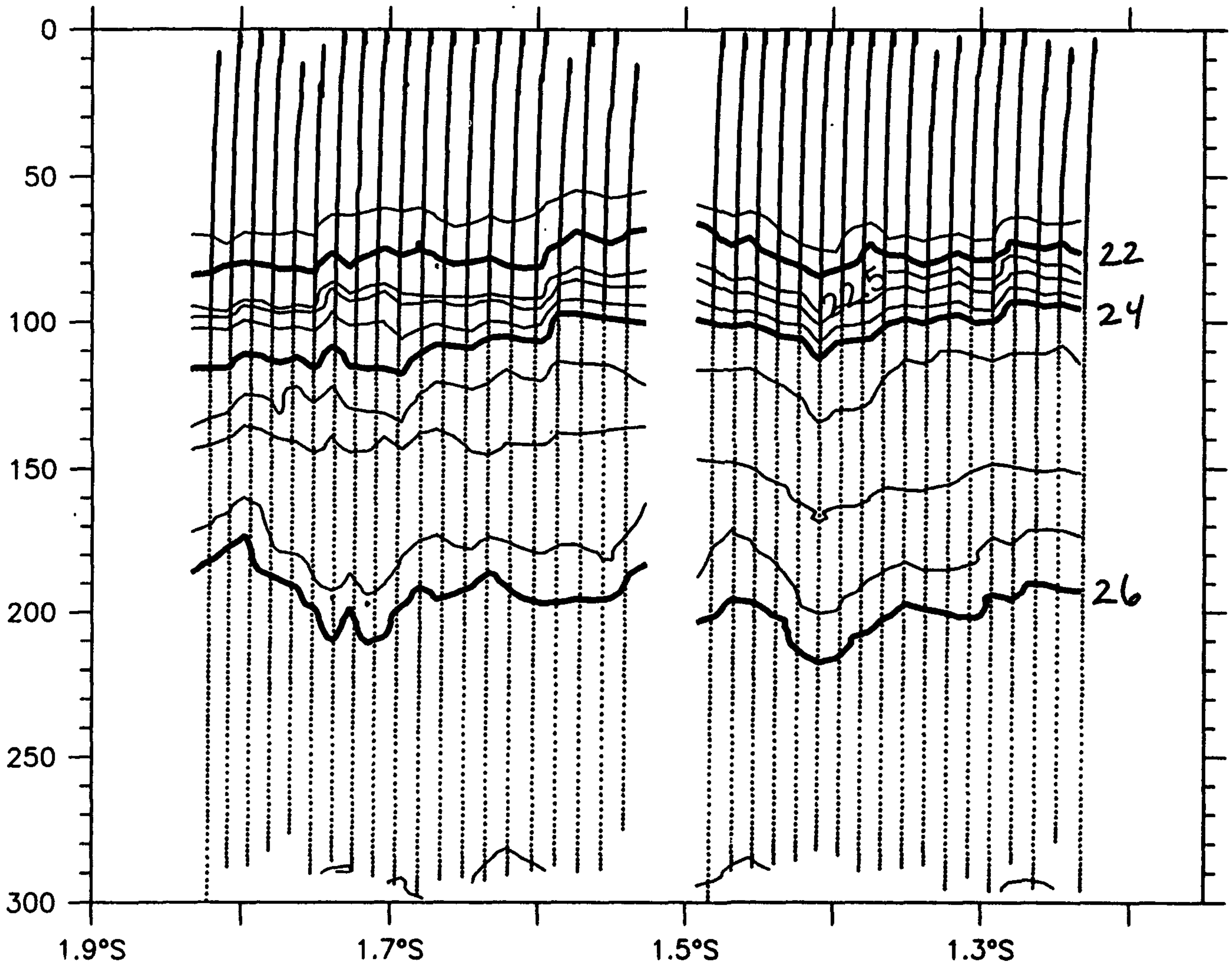
Sigma-t, E2N, 06 February 1993



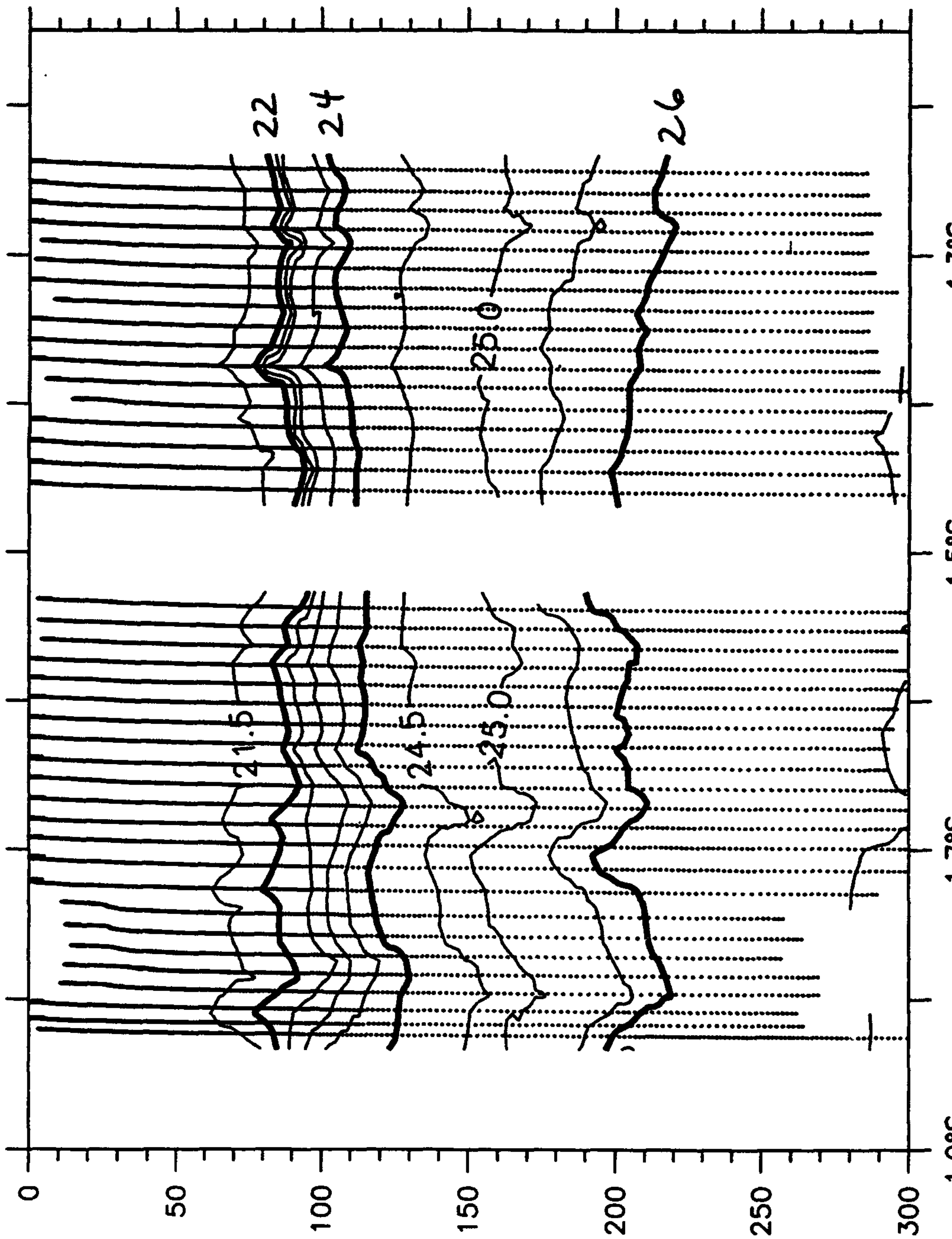
Sigma−t, E2N, 9 February 1993



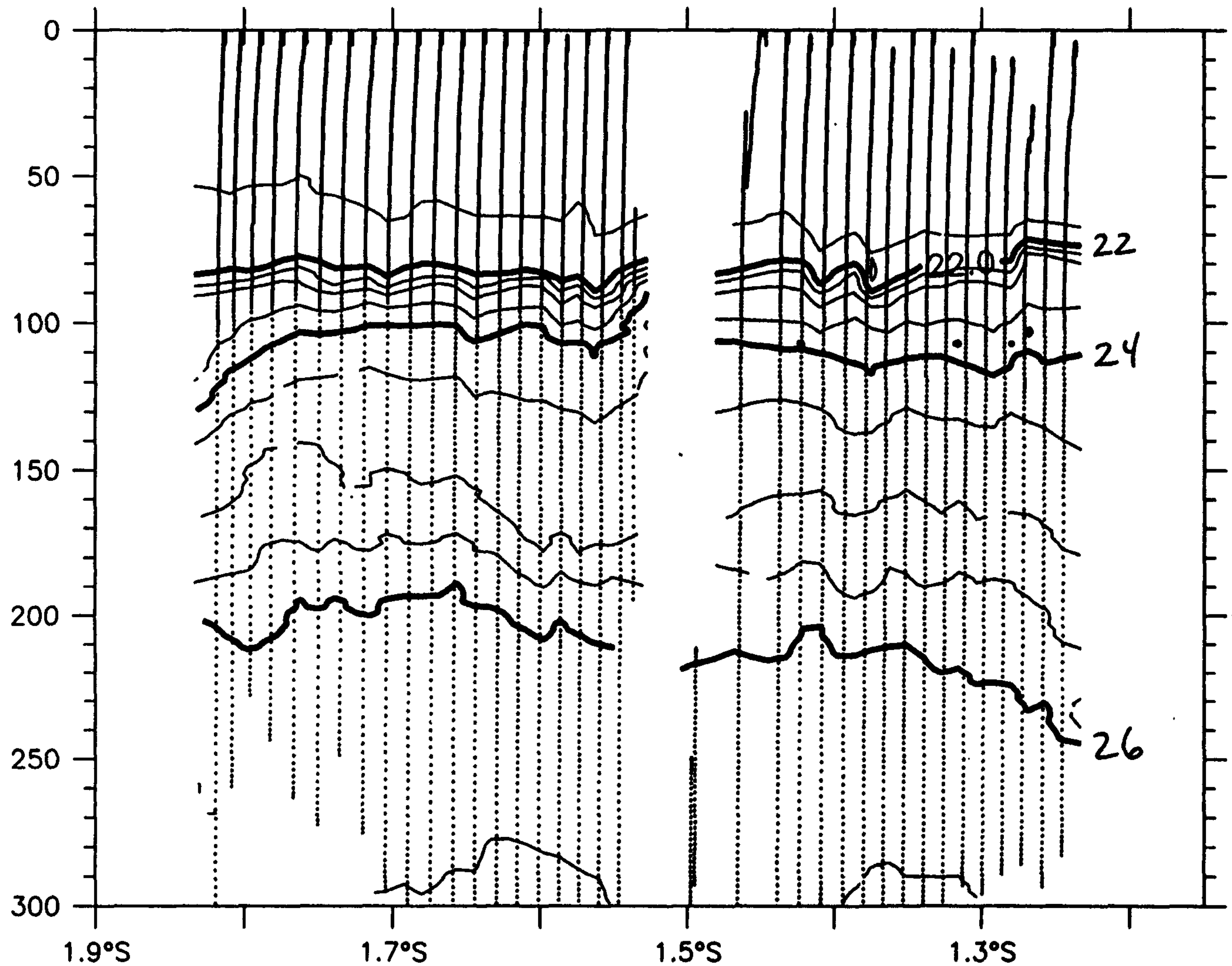
Sigma-t, E2N, 10 February 1993



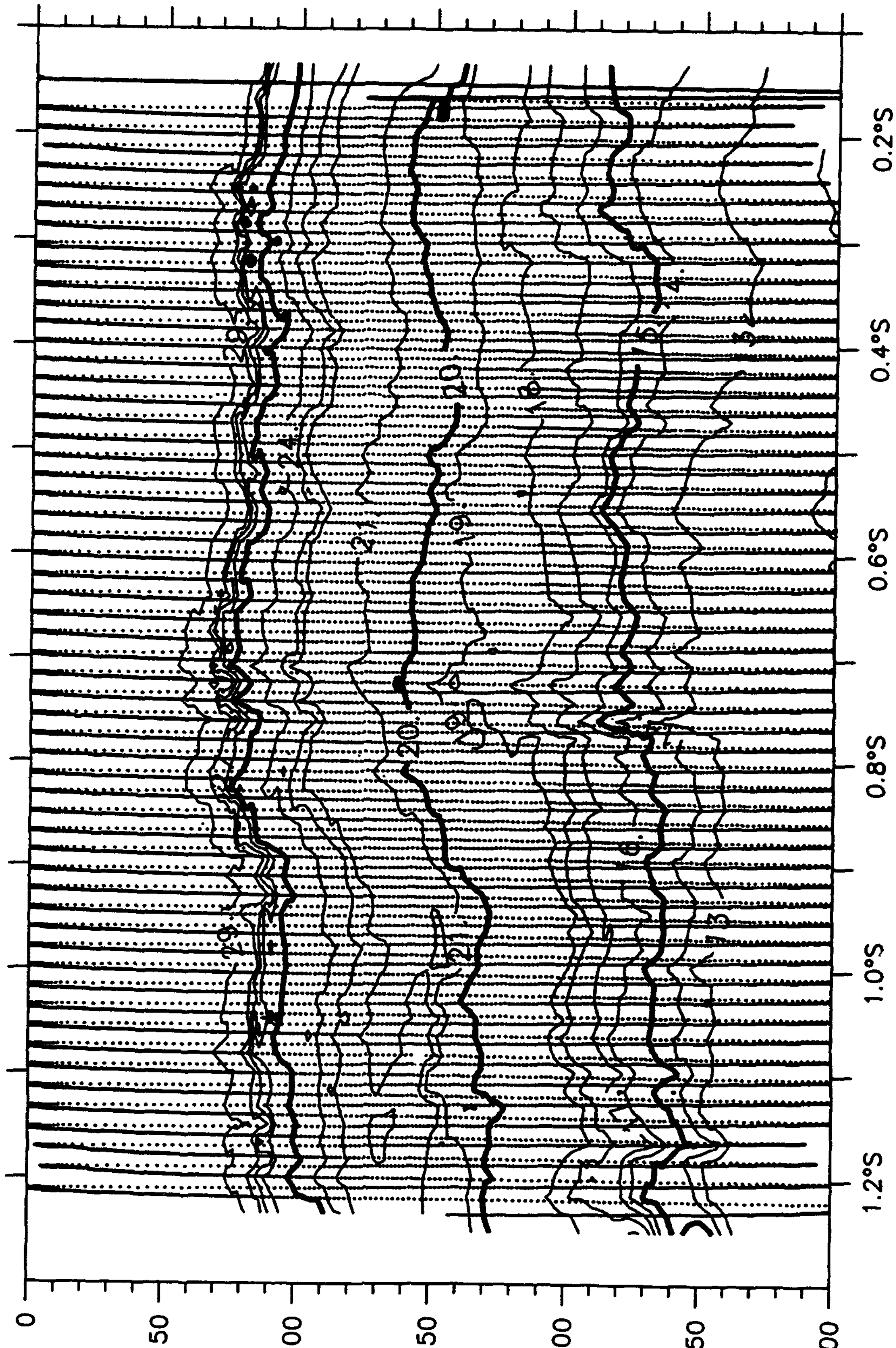
Sigma–t, E2N, 11 February 1993



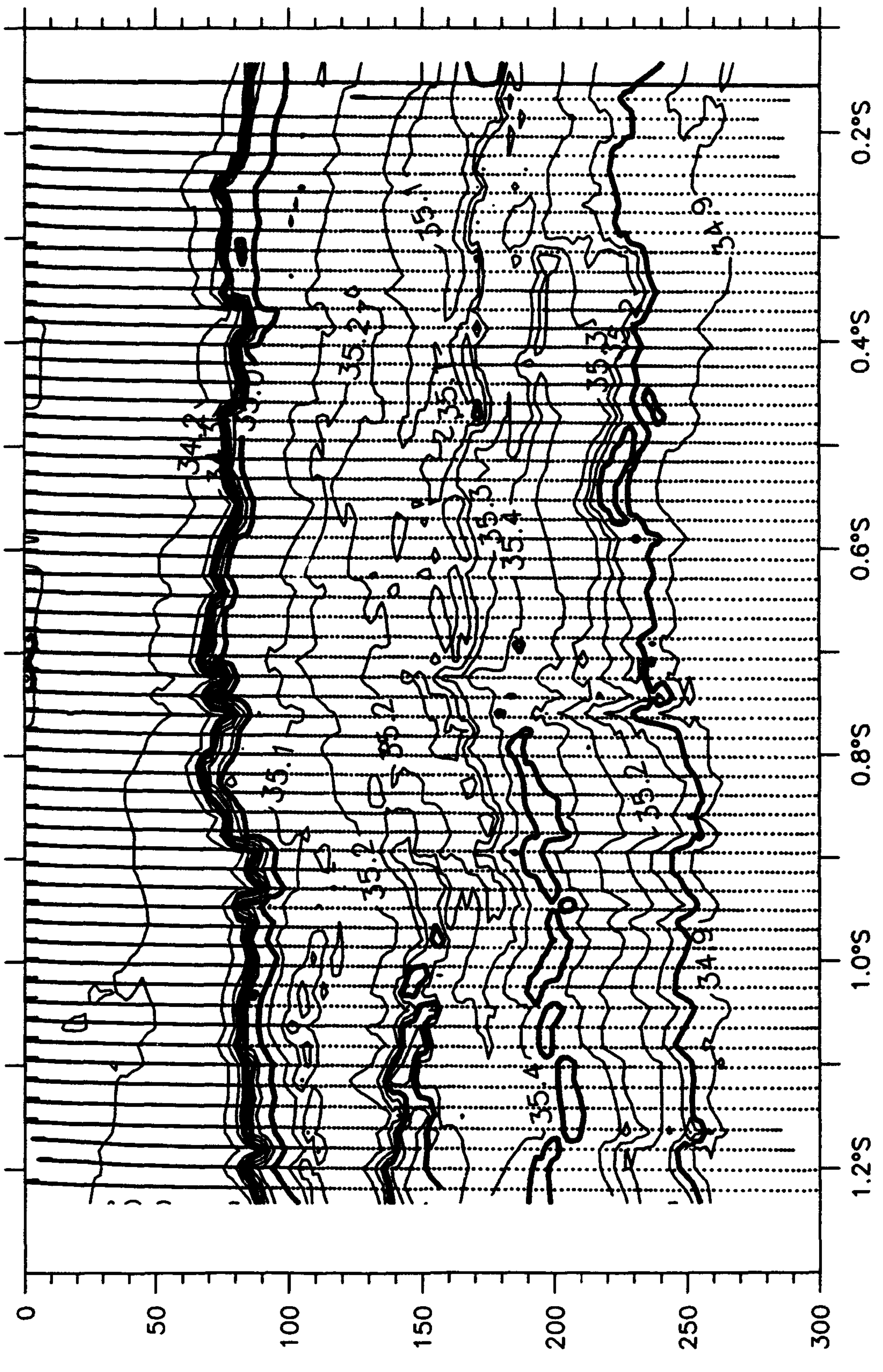
Sigma-t, E2N, 13 February 1993



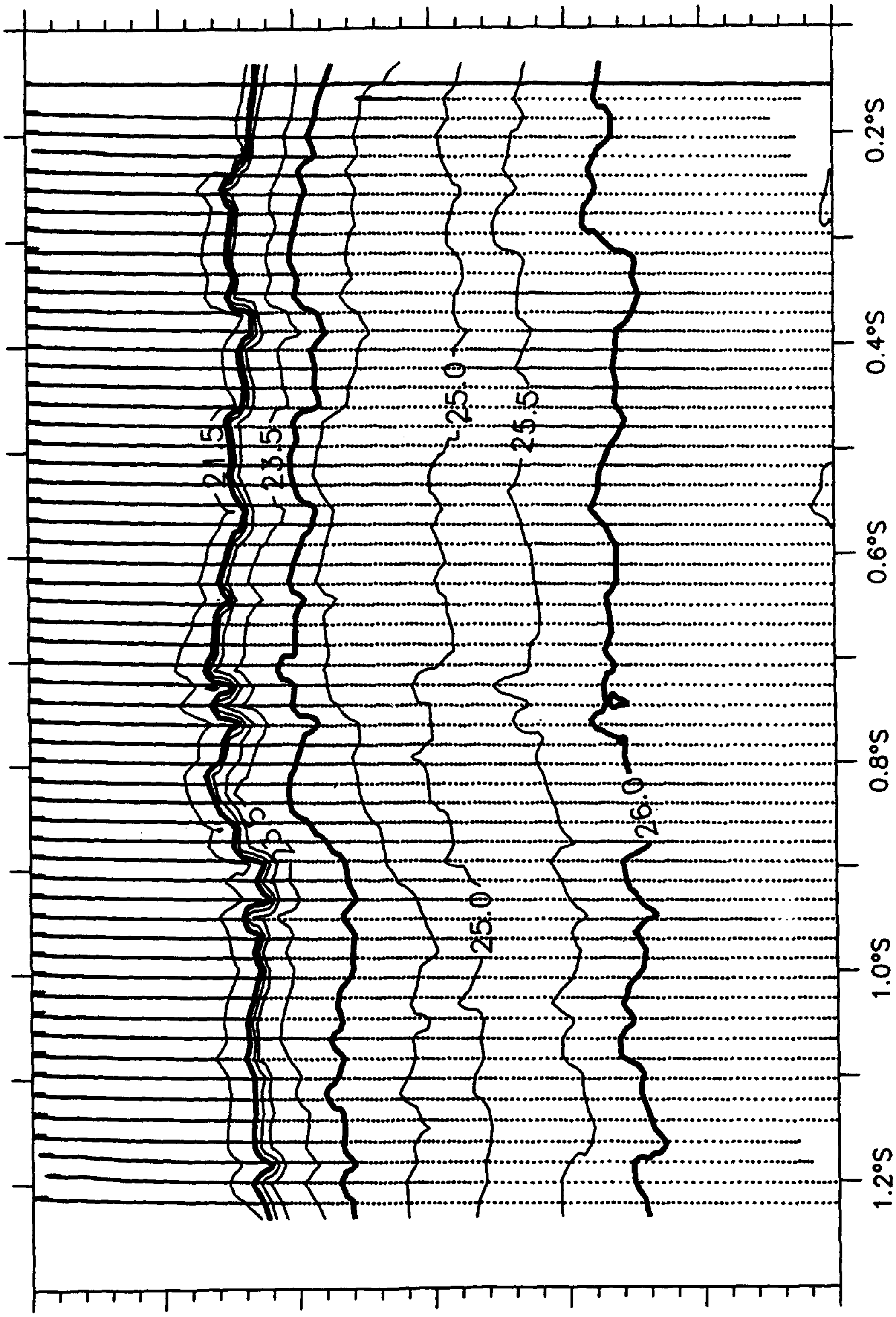
Sigma-t, E2N, 15 February 1993



T(°C), SBN to Equator, 15 February 1993



S(psu), SBN to Equator, 15 February 1993

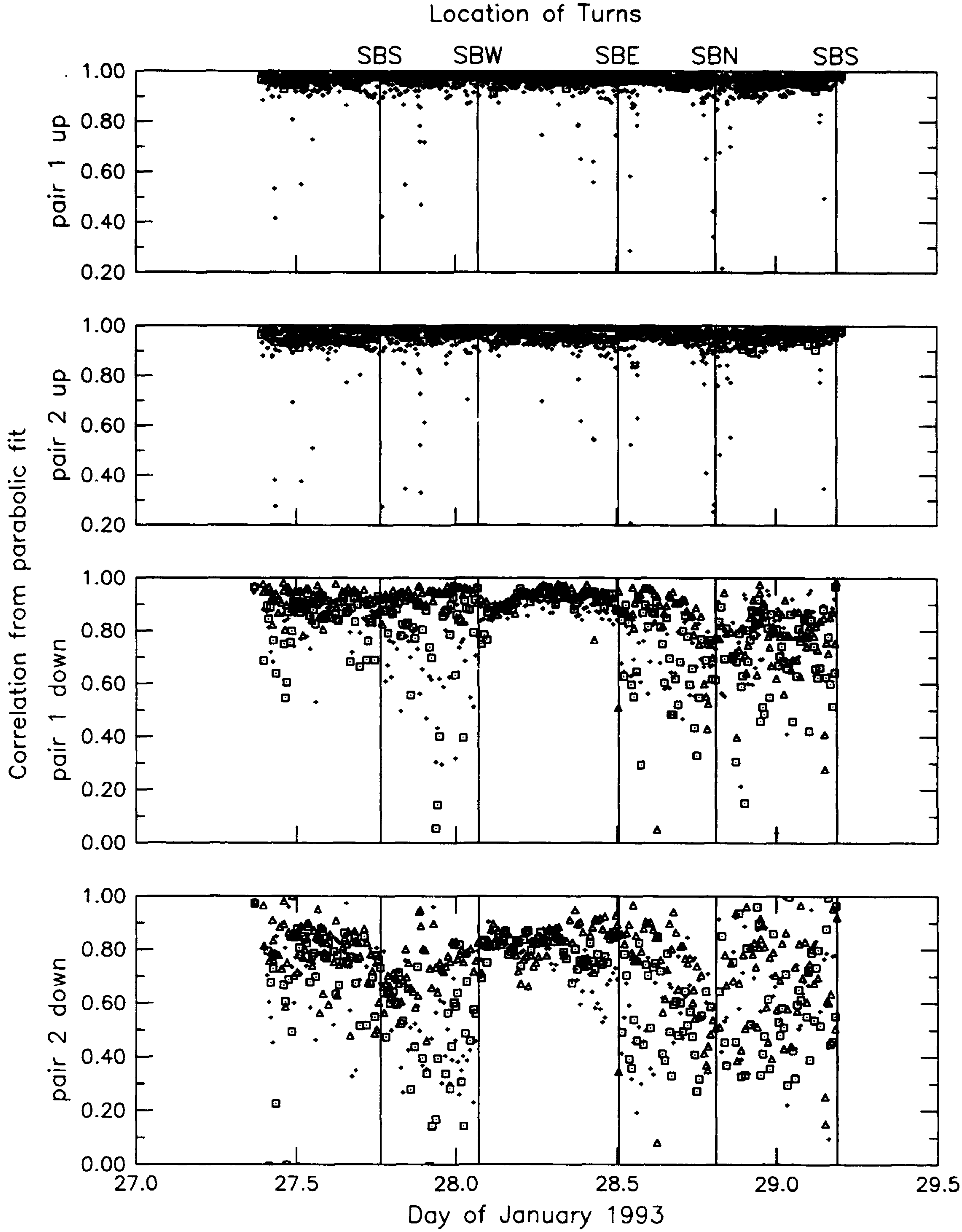


Sigma–t, SBN to Equator, 15 February 1993

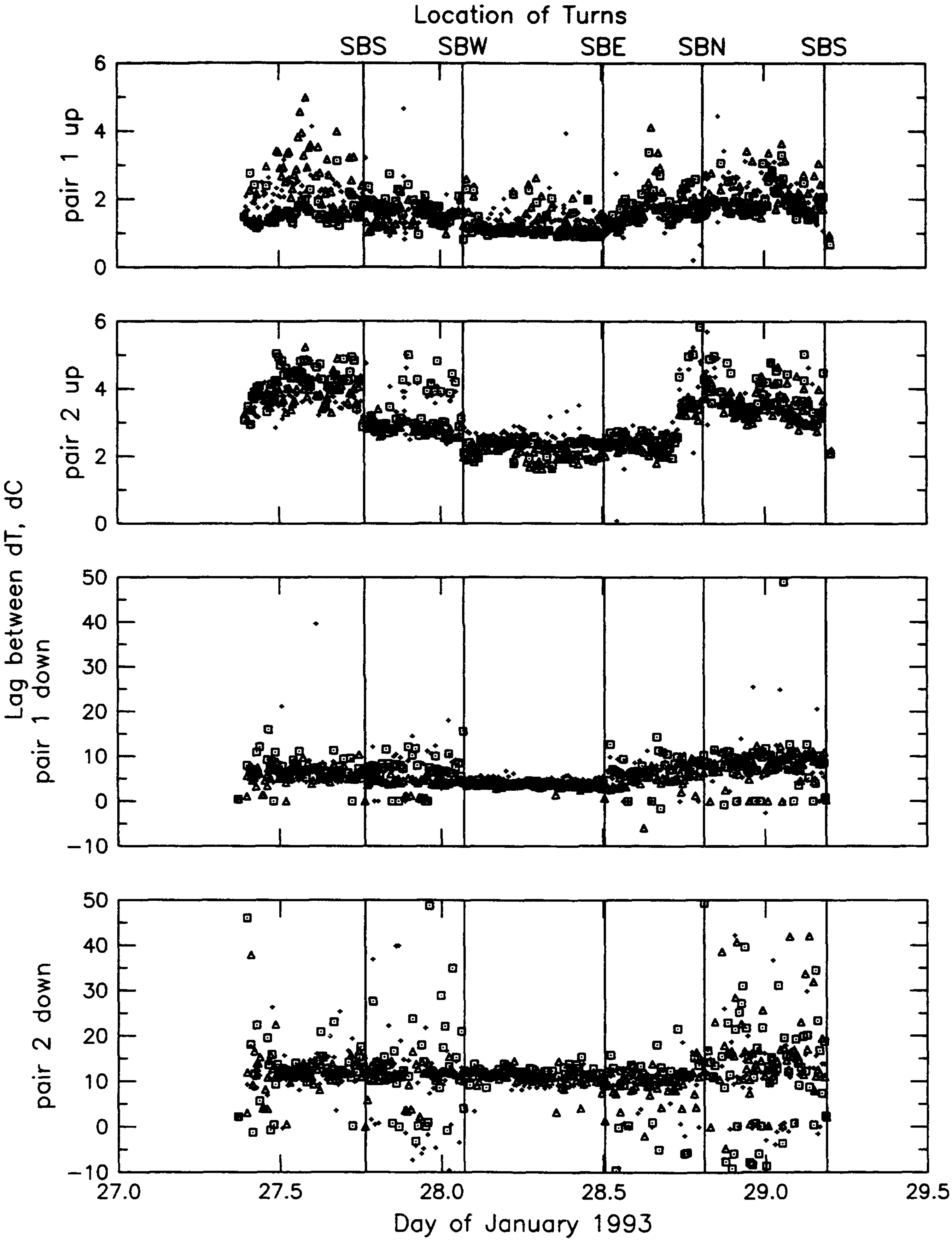
APPENDIX A:

Time Series of Lag of Maximum T/C Correlation

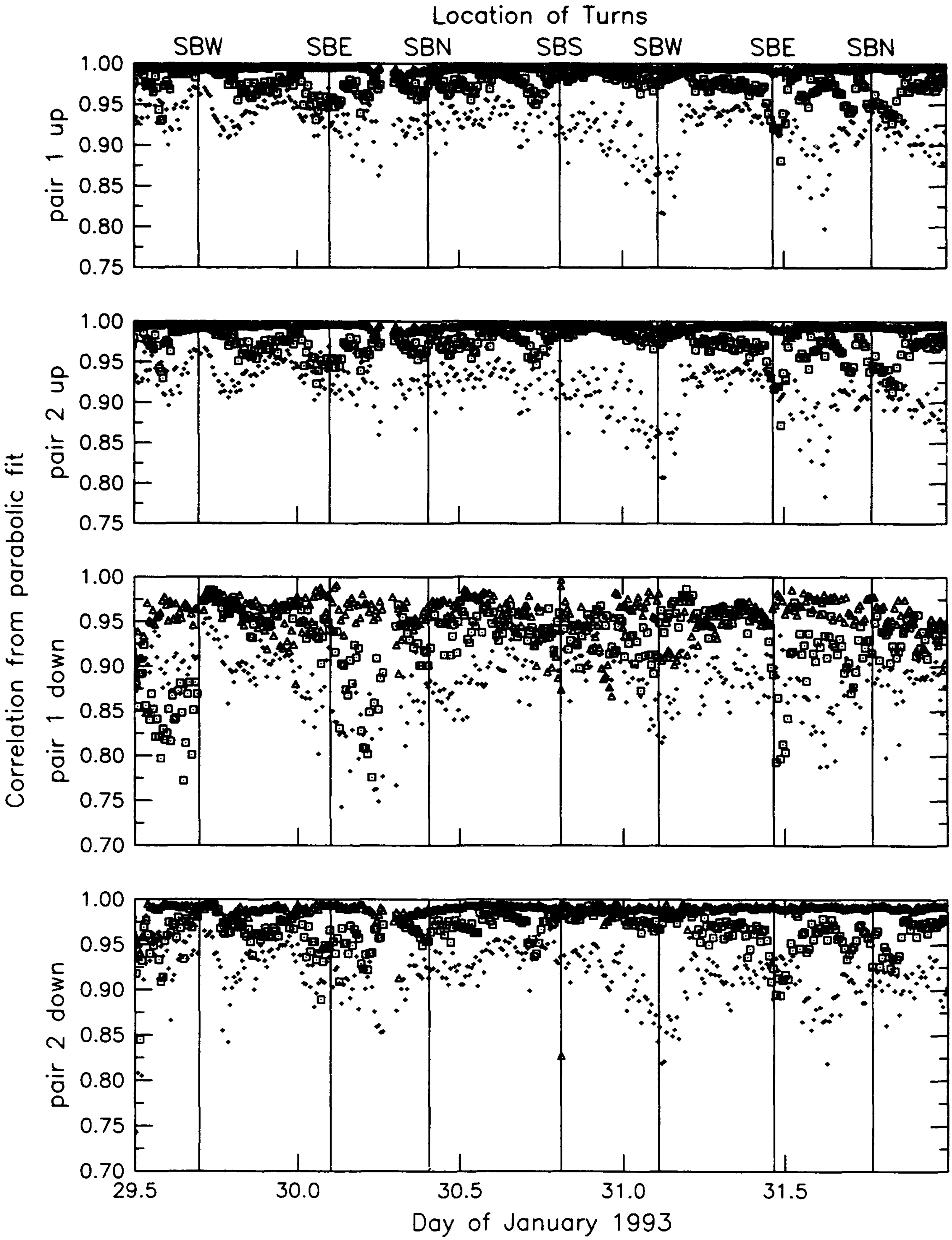
for Seasoar Tows 2-6



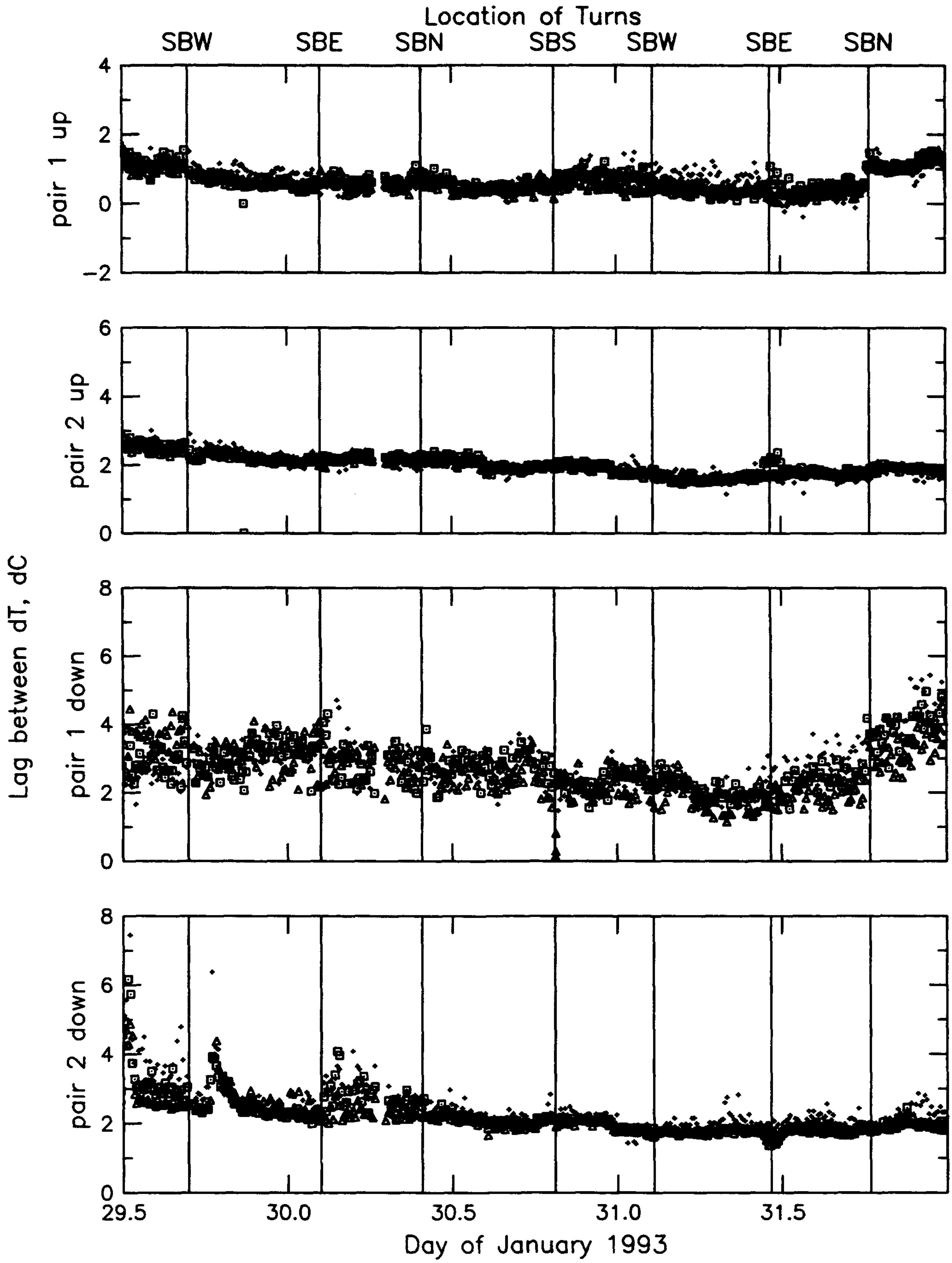
Leg 3 Tow 2, 50−120 db (plus), 120−180 db (square), 180−240 db (triangle



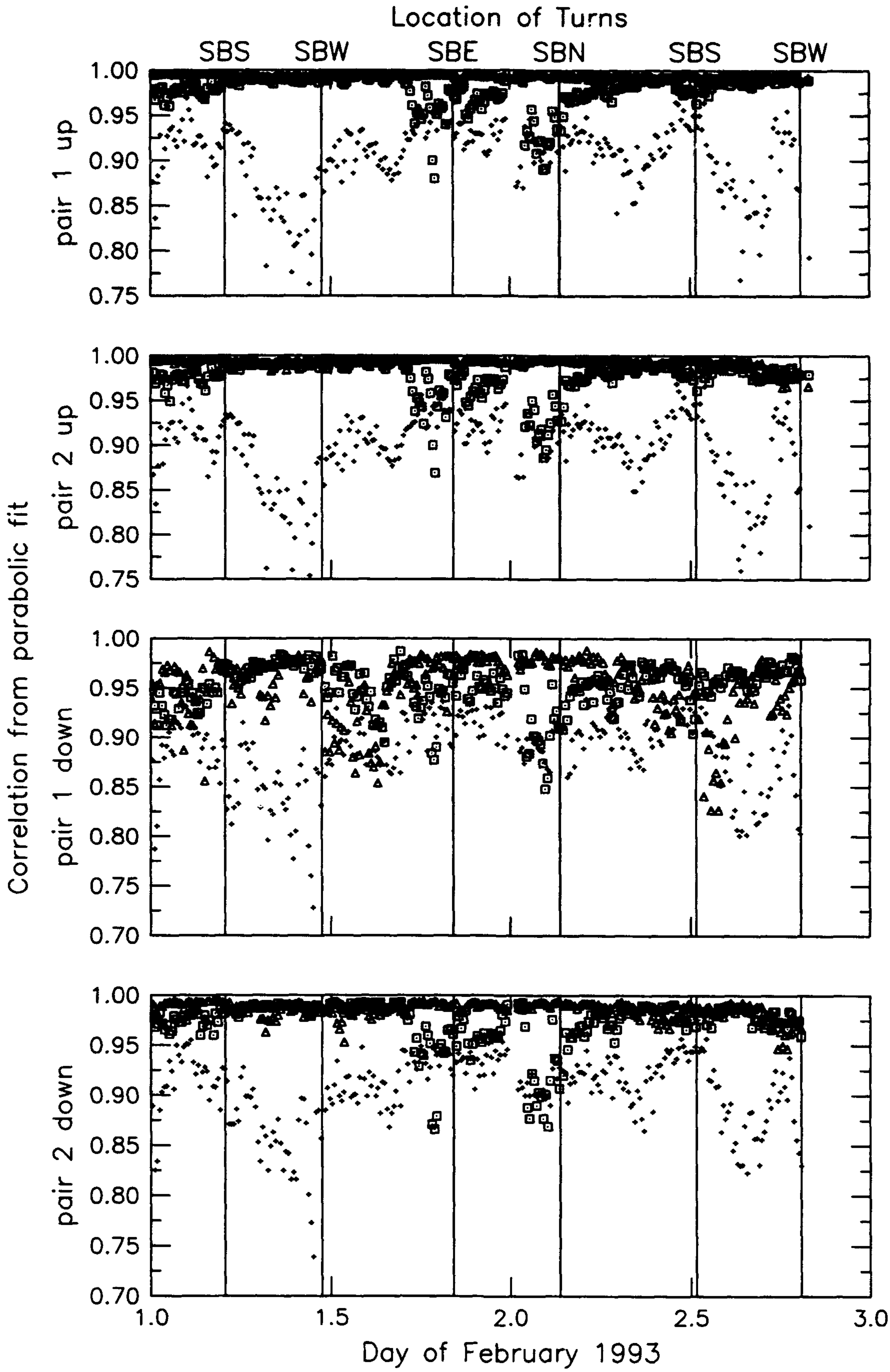
Leg 3 Tow 2, 50−120 db (plus), 120−180 db (square), 180−240 db (triangle



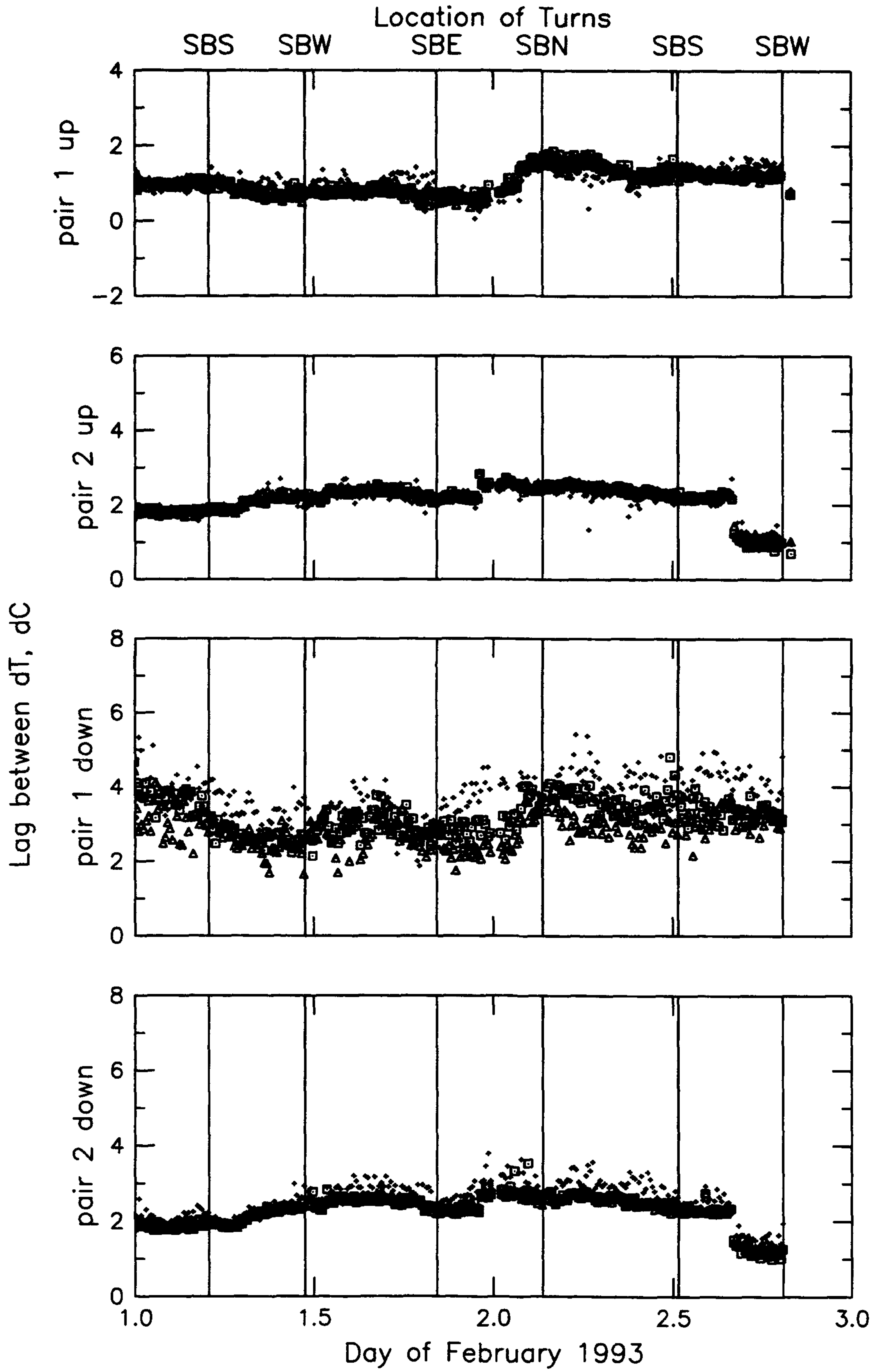
Leg 3 Tow 3, 50−120 db (plus), 120−180 db (square), 180−240 db (triangl



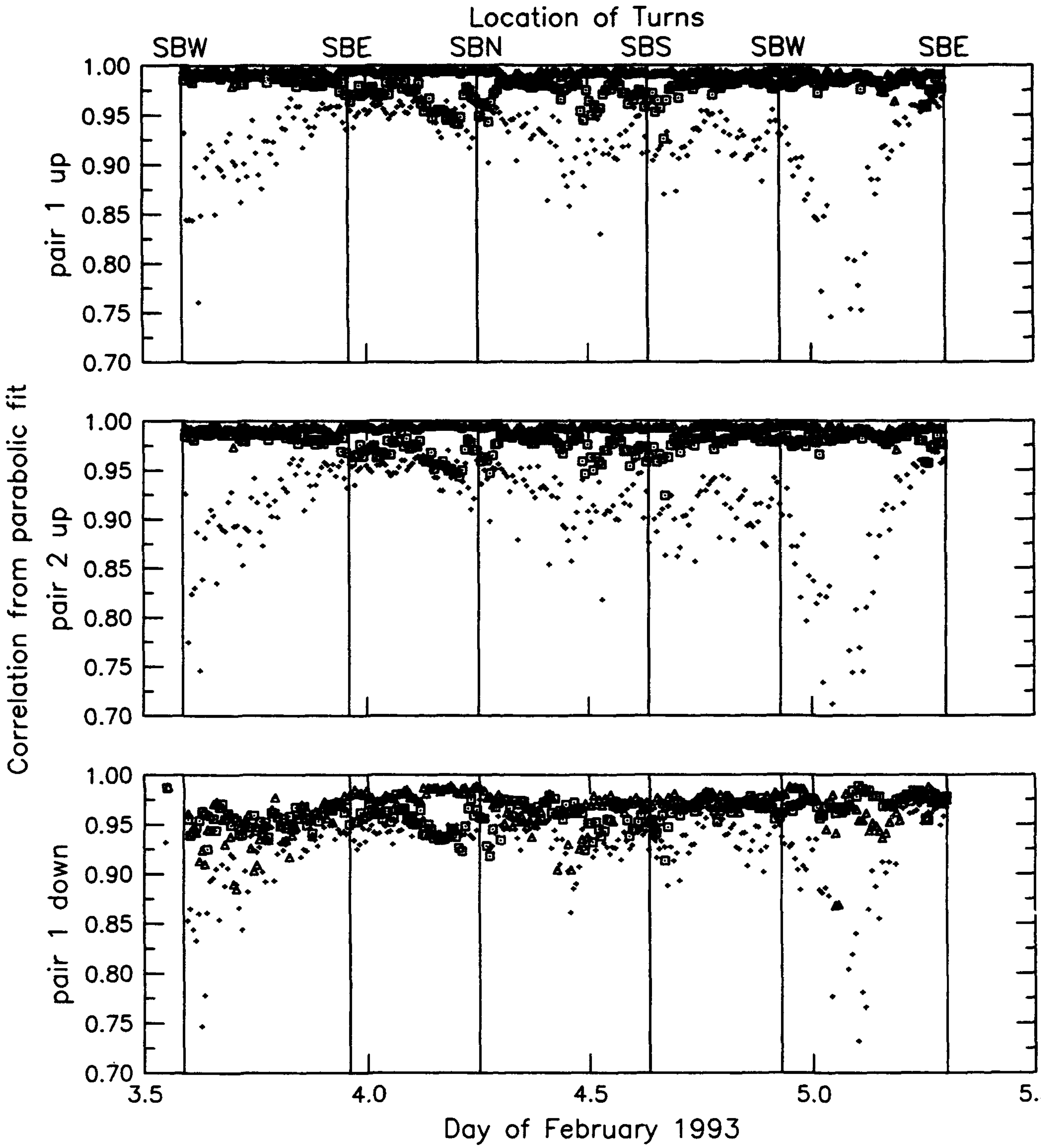
Leg 3 Tow 3, 50–120 db (plus), 120–180 db (square), 180–240 db (triangle



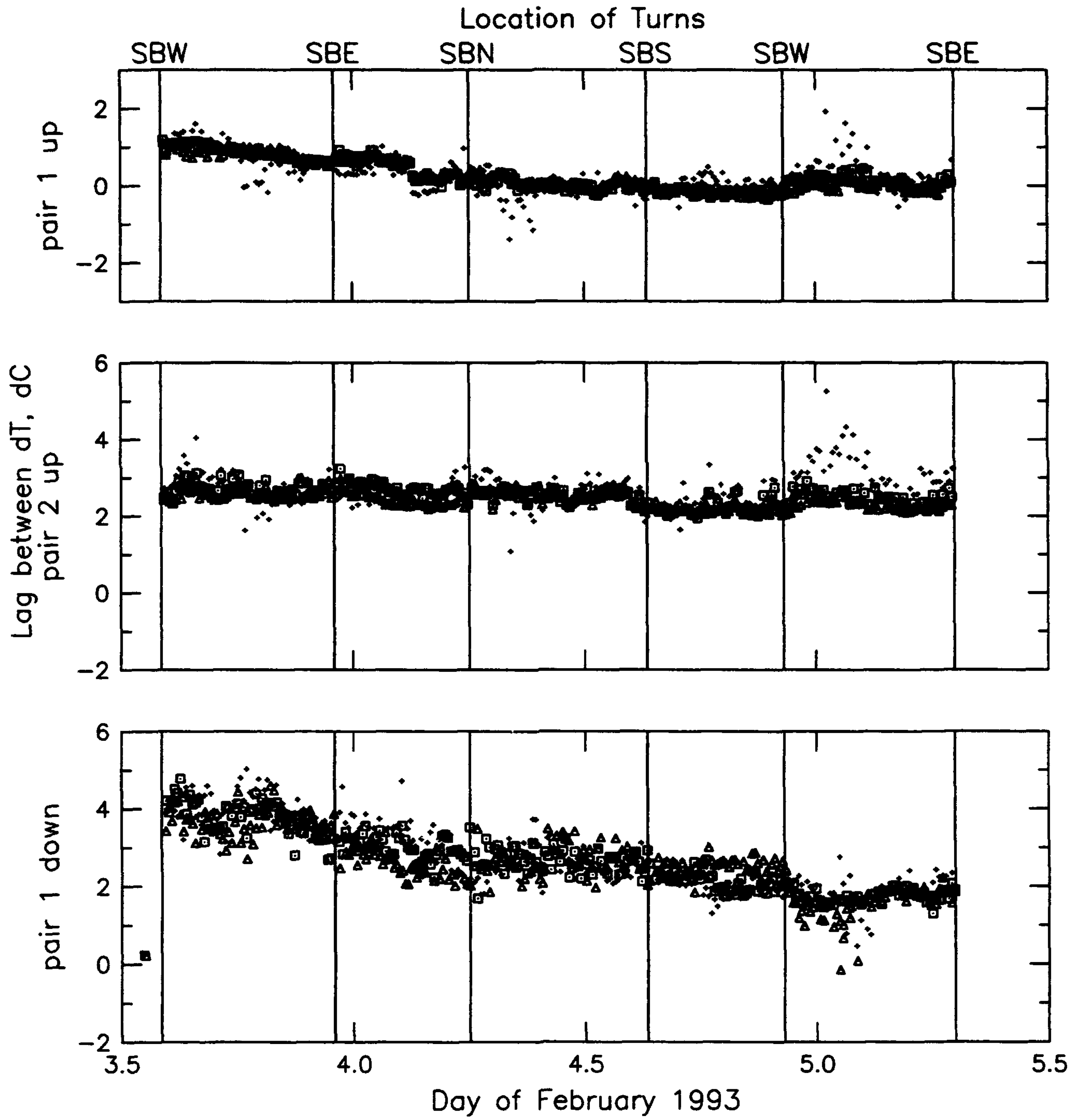
Leg 3 Tow 3, 50−120 db (plus), 120−180 db (square), 180−240 db (triangle)



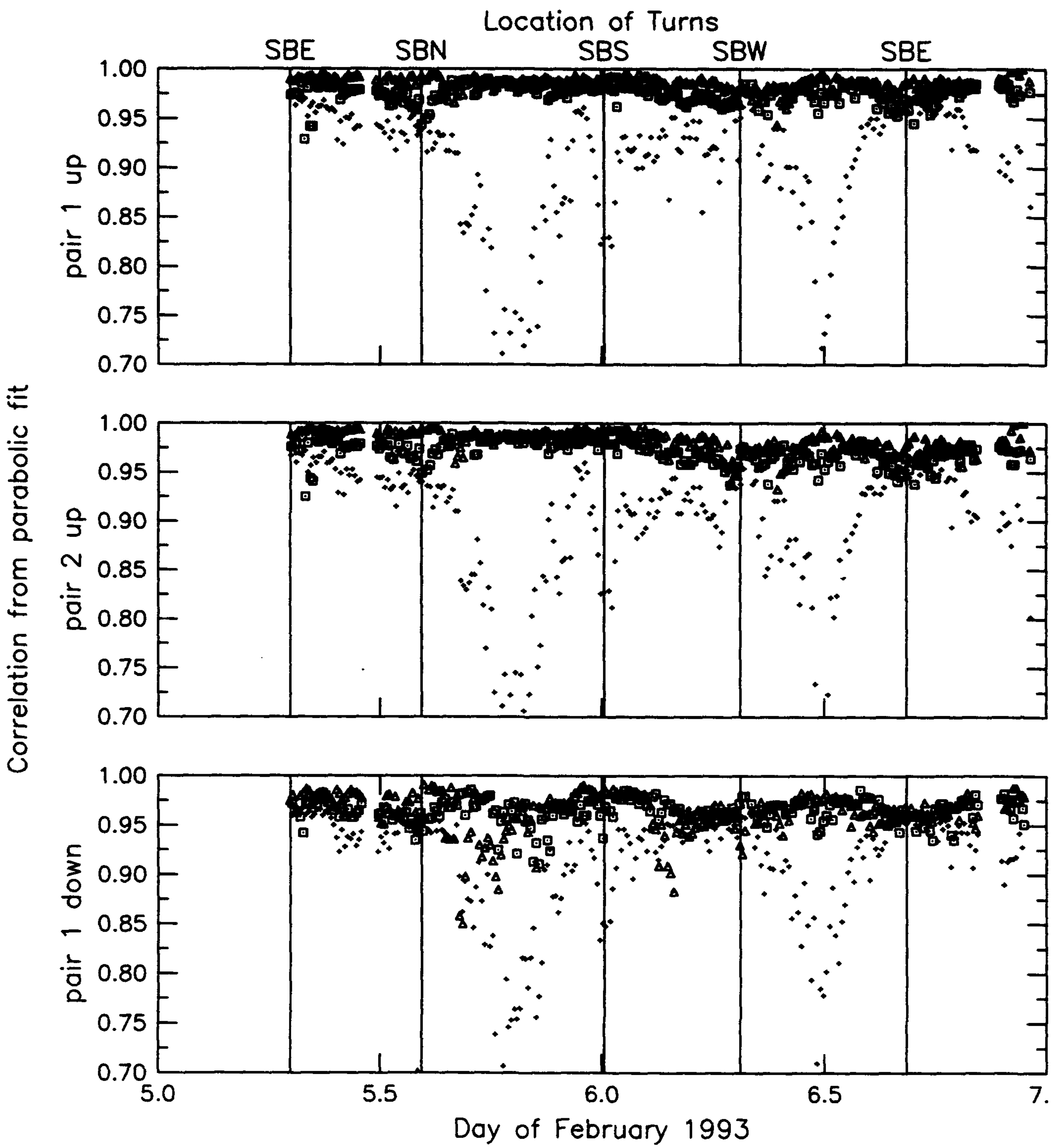
Leg 3 Tow 3, 50–120 db (plus), 120–180 db (square), 180–240 db (triangle)



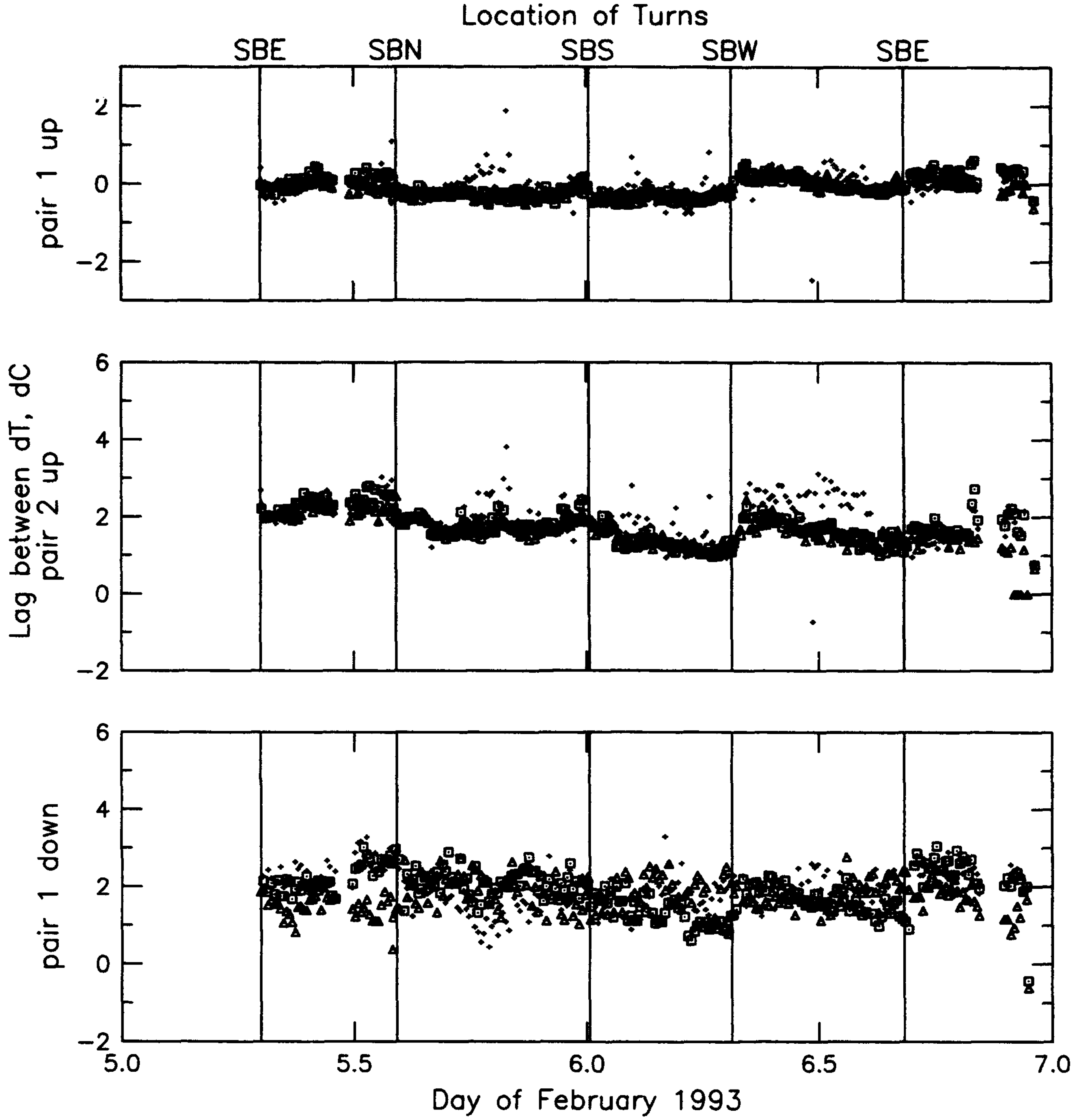
Leg 3 Tow 4, 50–120 db (plus), 120–180 db (square), 180–240 db (triangl



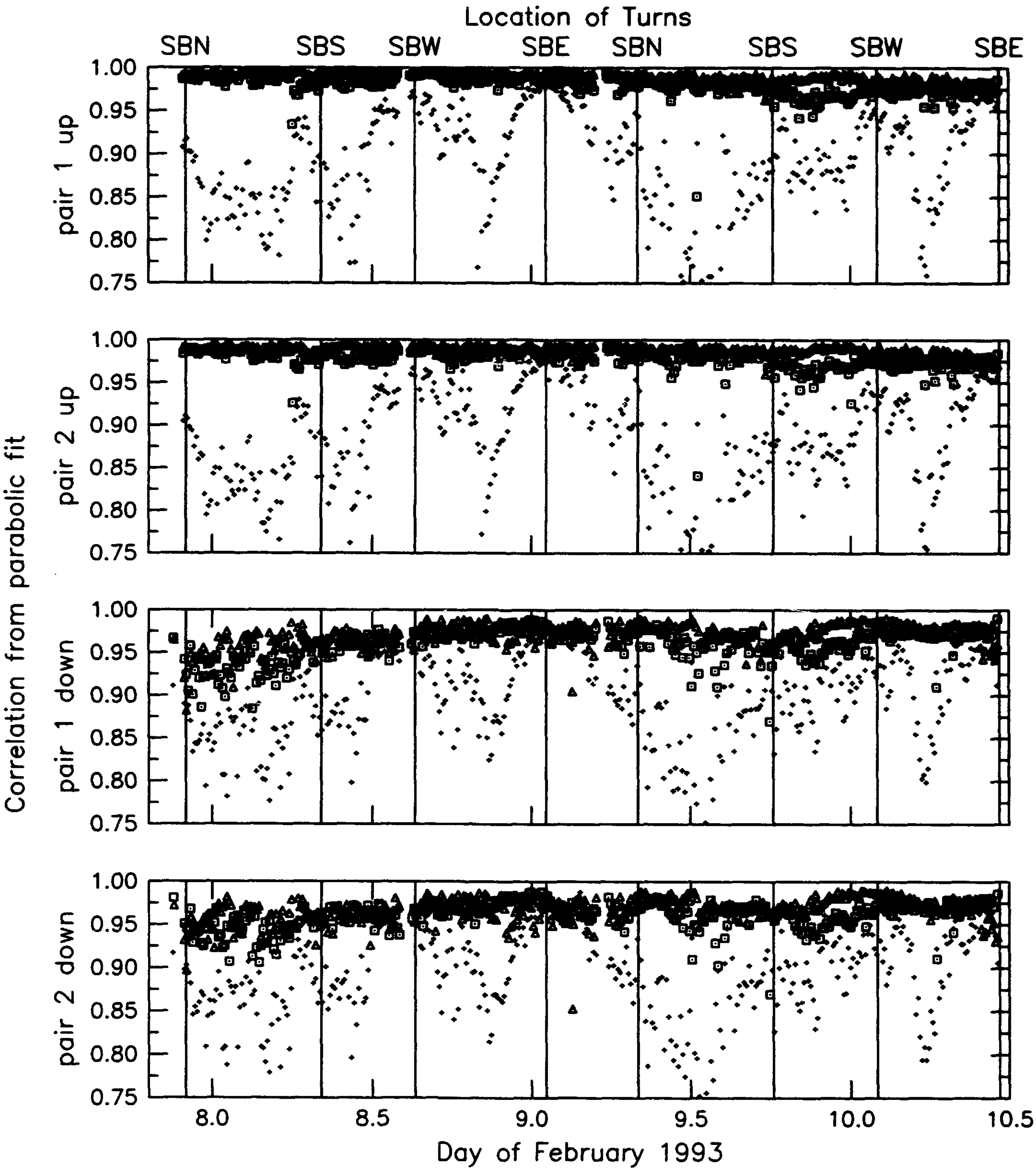
Leg 3 Tow 4, 50–120 db (plus), 120–180 db (square), 180–240 db (triangle



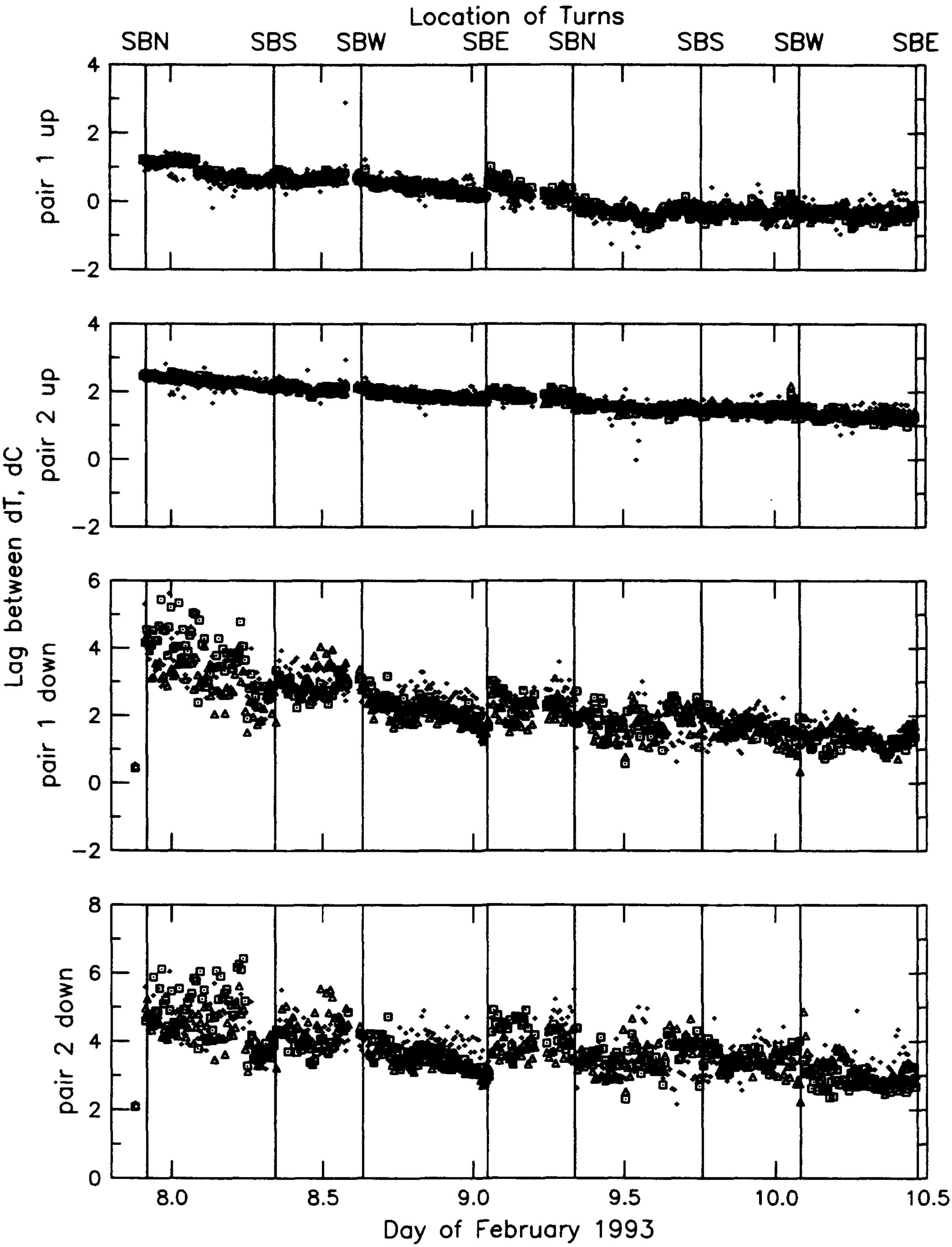
Leg 3 Tow 4, 50–120 db (plus), 120–180 db (square), 180–240 db (triangl



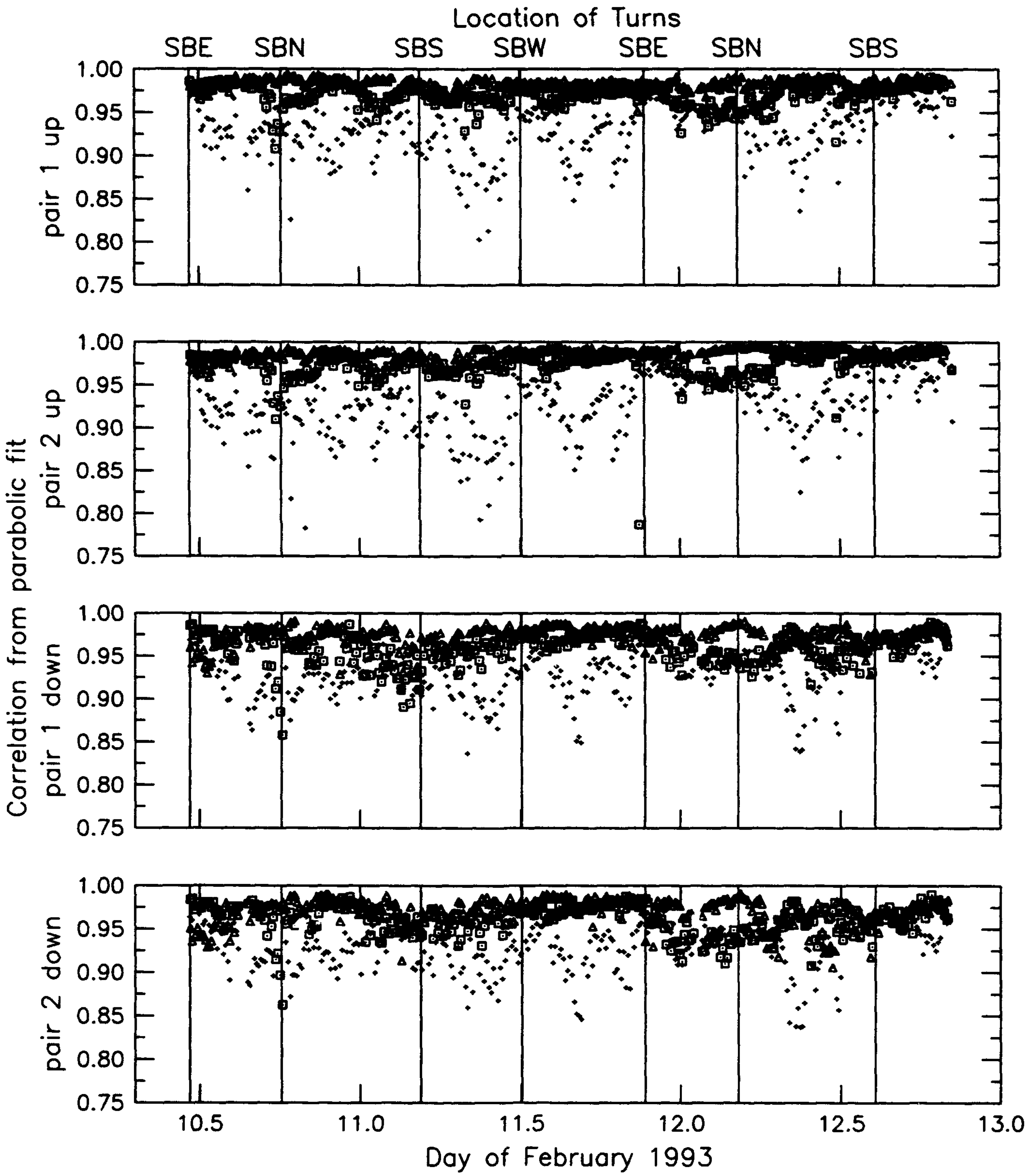
Leg 3 Tow 4, 50−120 db (plus), 120−180 db (square), 180−240 db (triangle



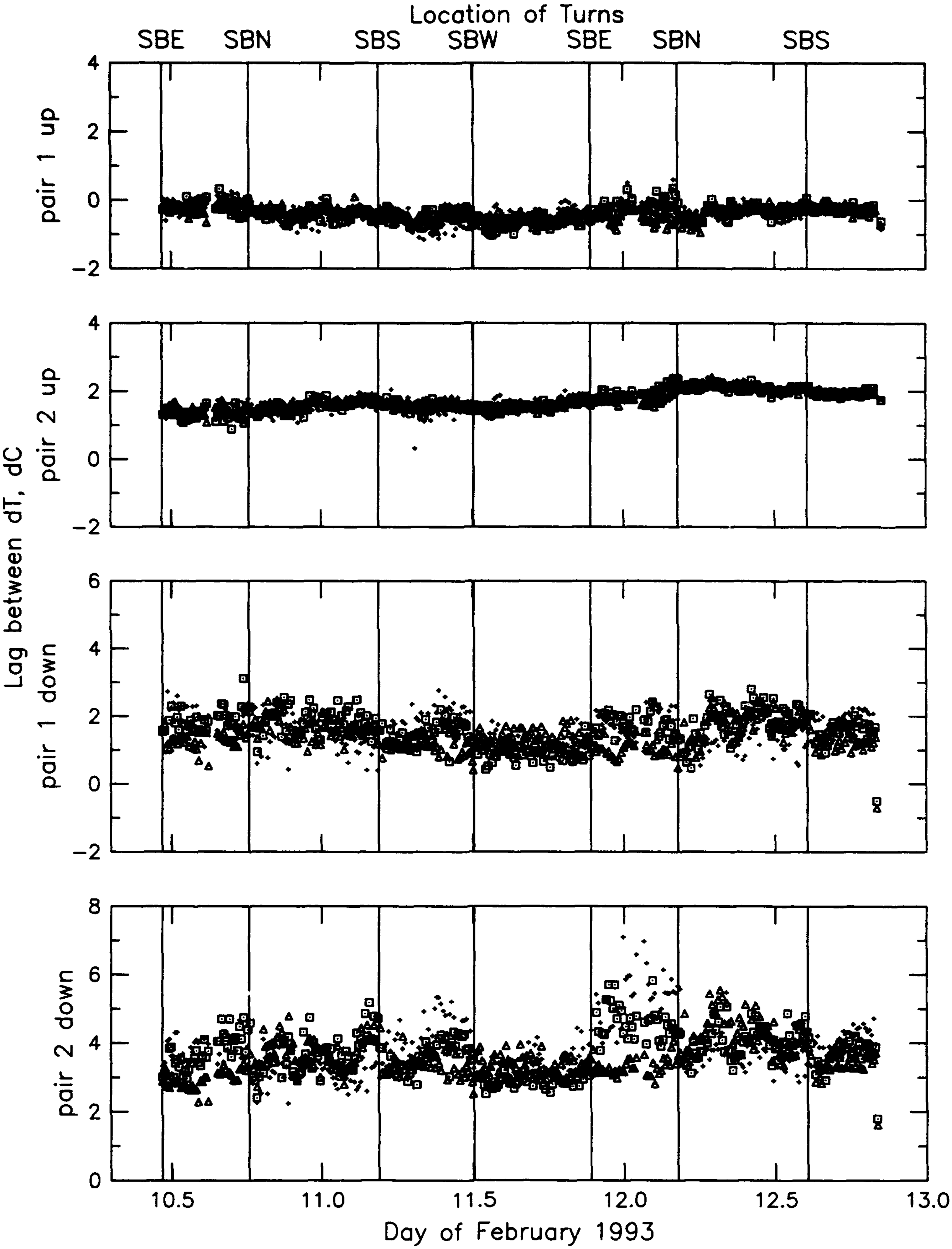
Leg 3 Tow 5, 50–120 db (plus), 120–180 db (square), 180–240 db (triangle



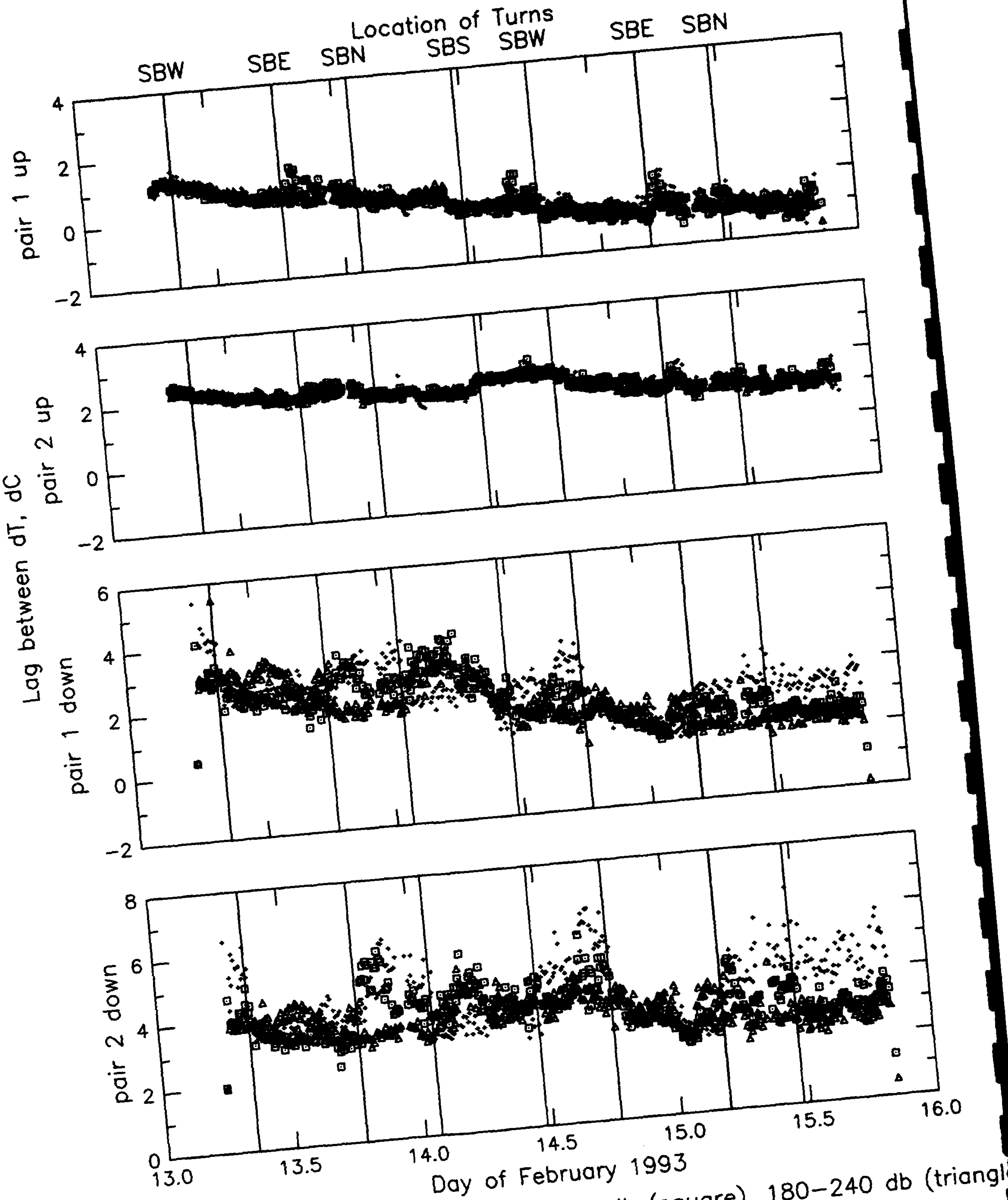
Leg 3 Tow 5, 50–120 db (plus), 120–180 db (square), 180–240 db (triangle



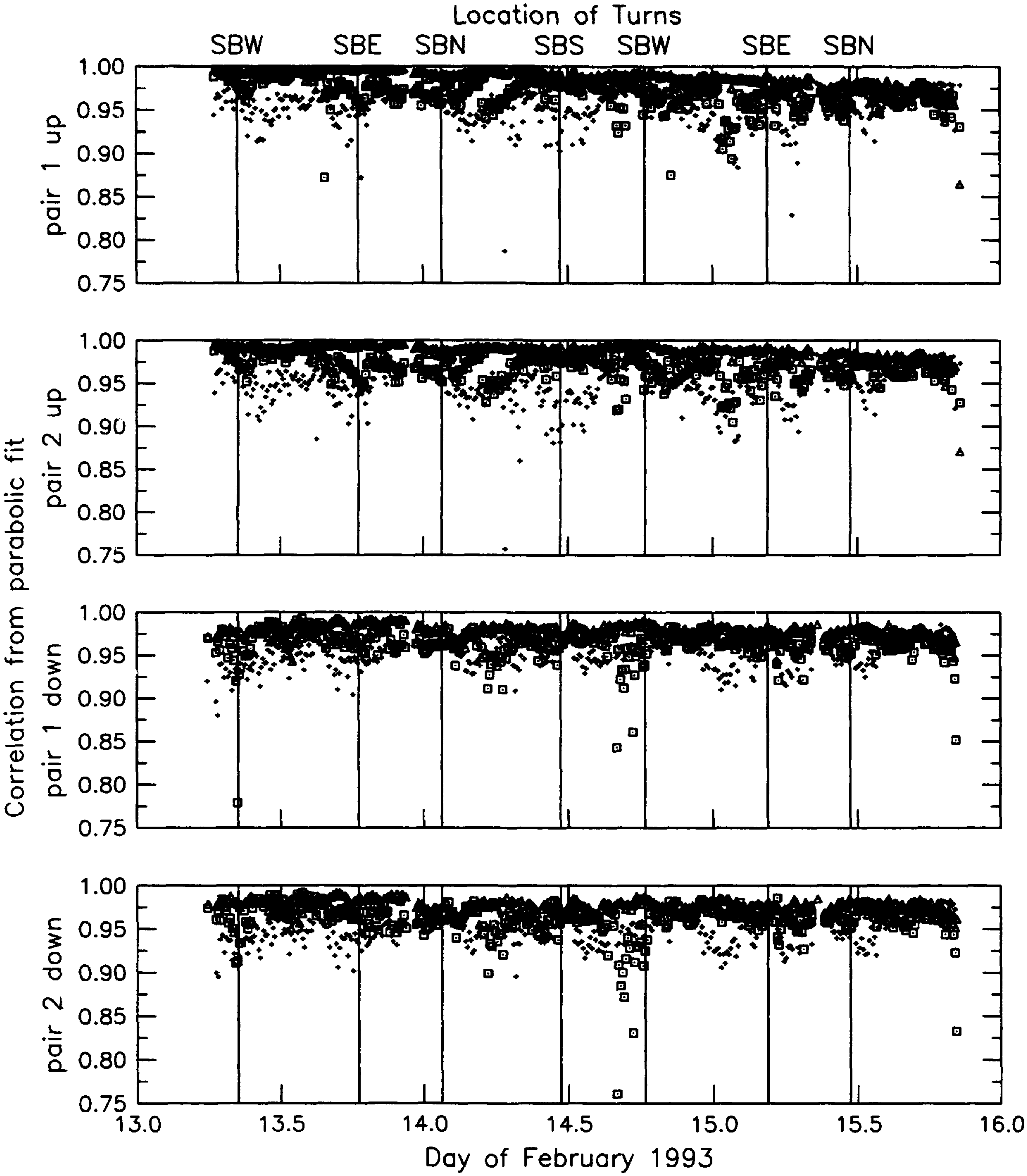
Leg 3 Tow 5, 50–120 db (plus), 120–180 db (square), 180–240 db (triangl



Leg 3 Tow 5, 50–120 db (plus), 120–180 db (square), 180–240 db (triangle



Leg 3 Tow 6, 50–120 db (plus), 120–180 db (square), 180–240 db (triangl

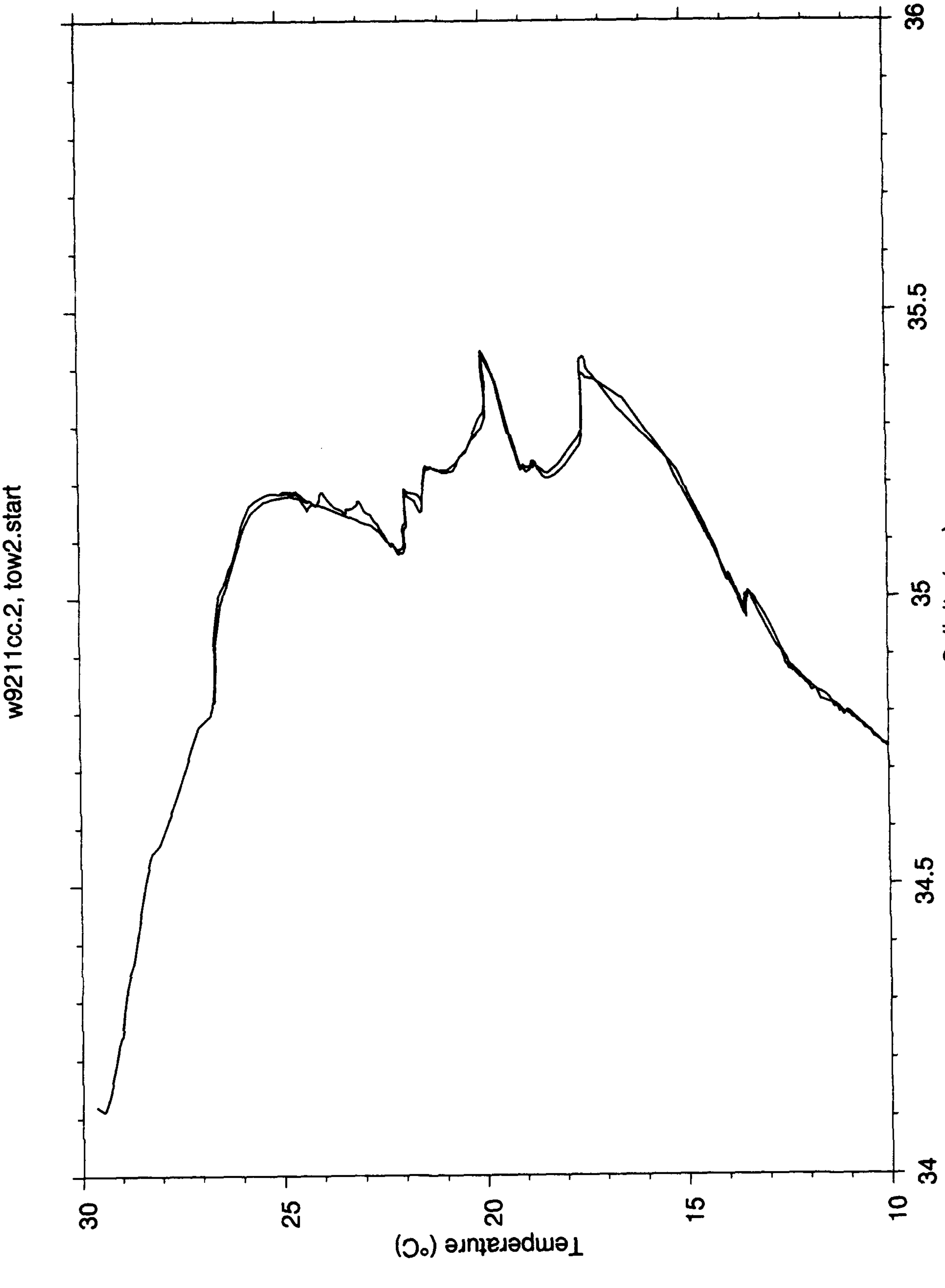


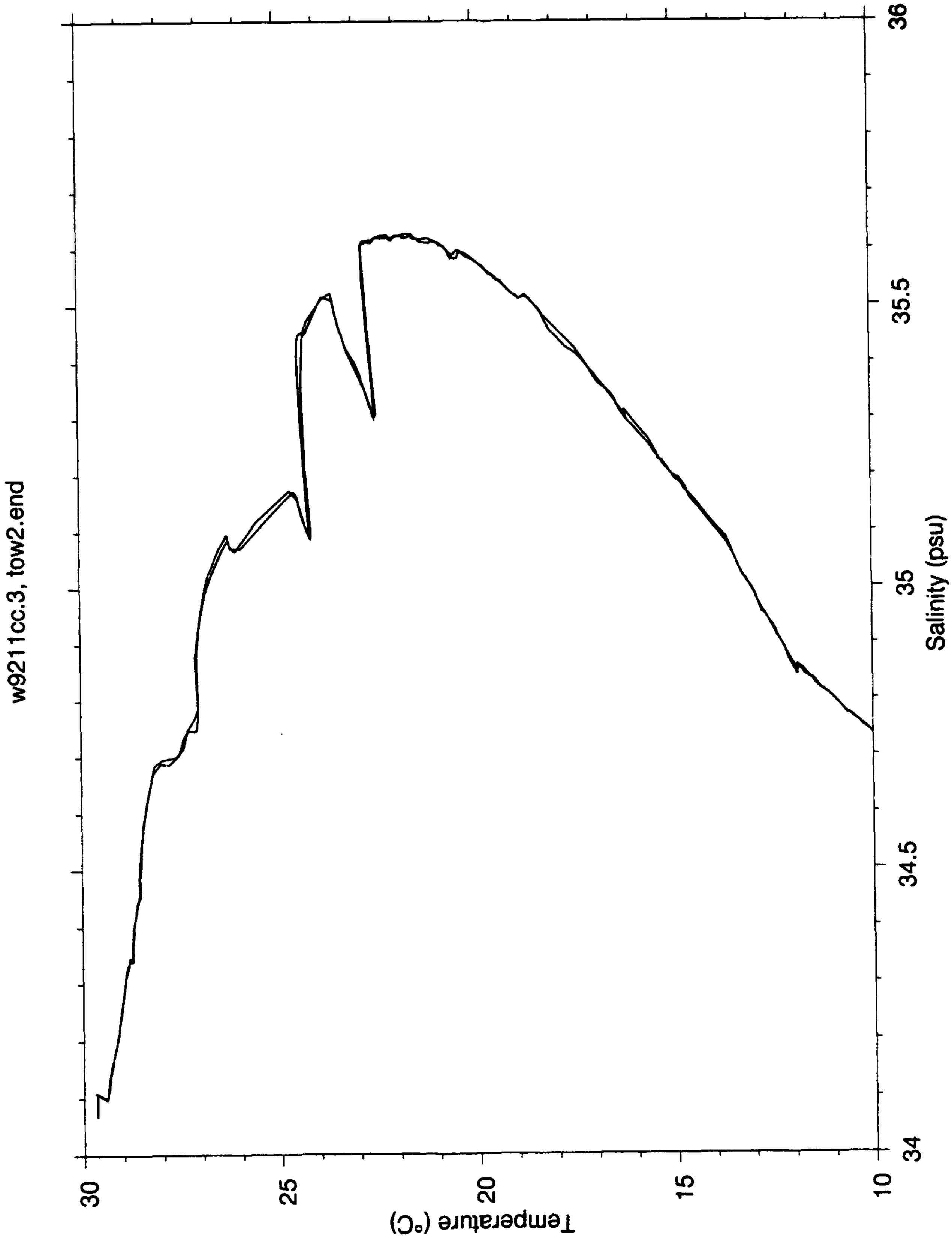
Leg 3 Tow 6, 50−120 db (plus), 120−180 db (square), 180−240 db (triangle

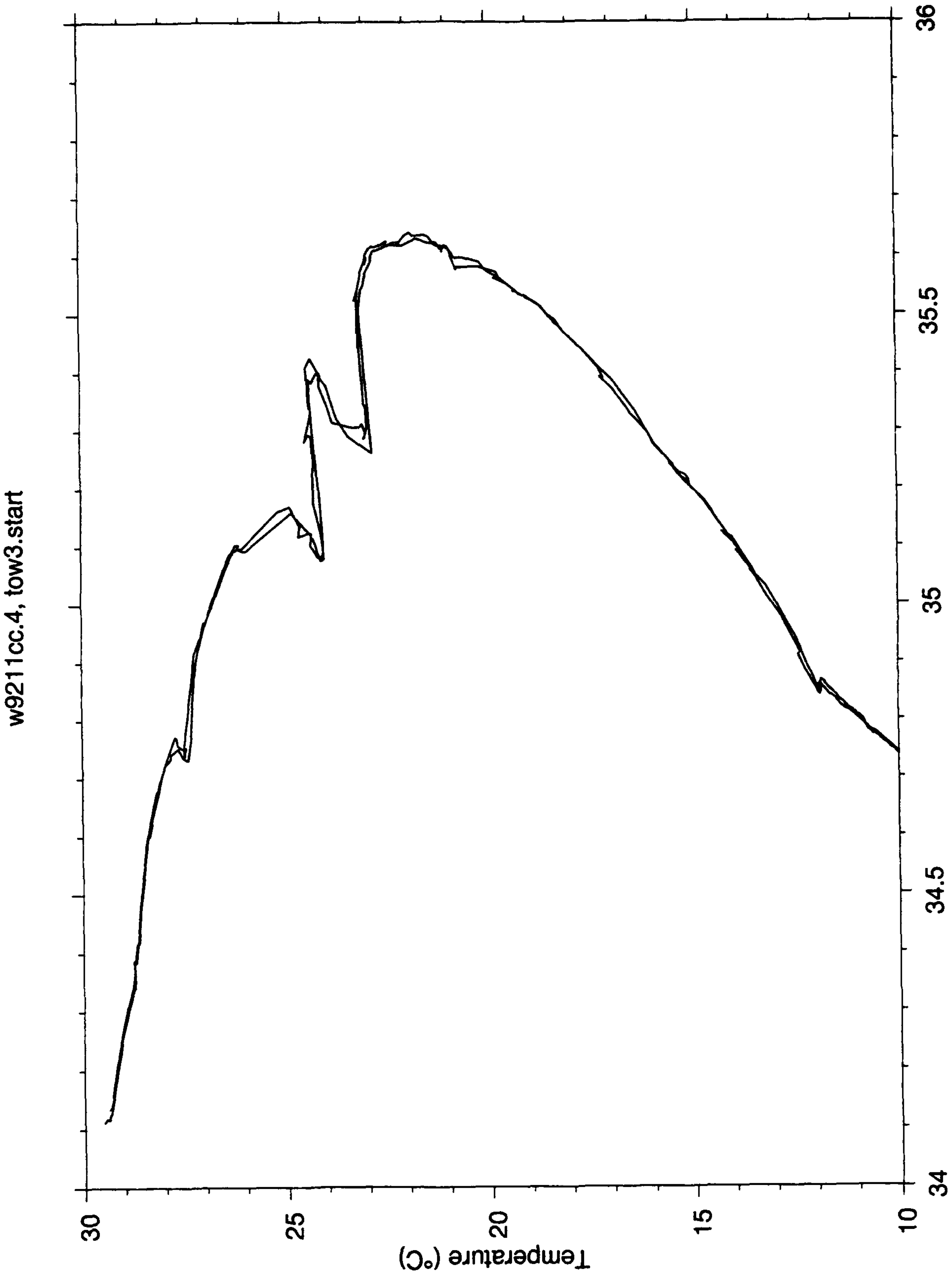
APPENDIX B:

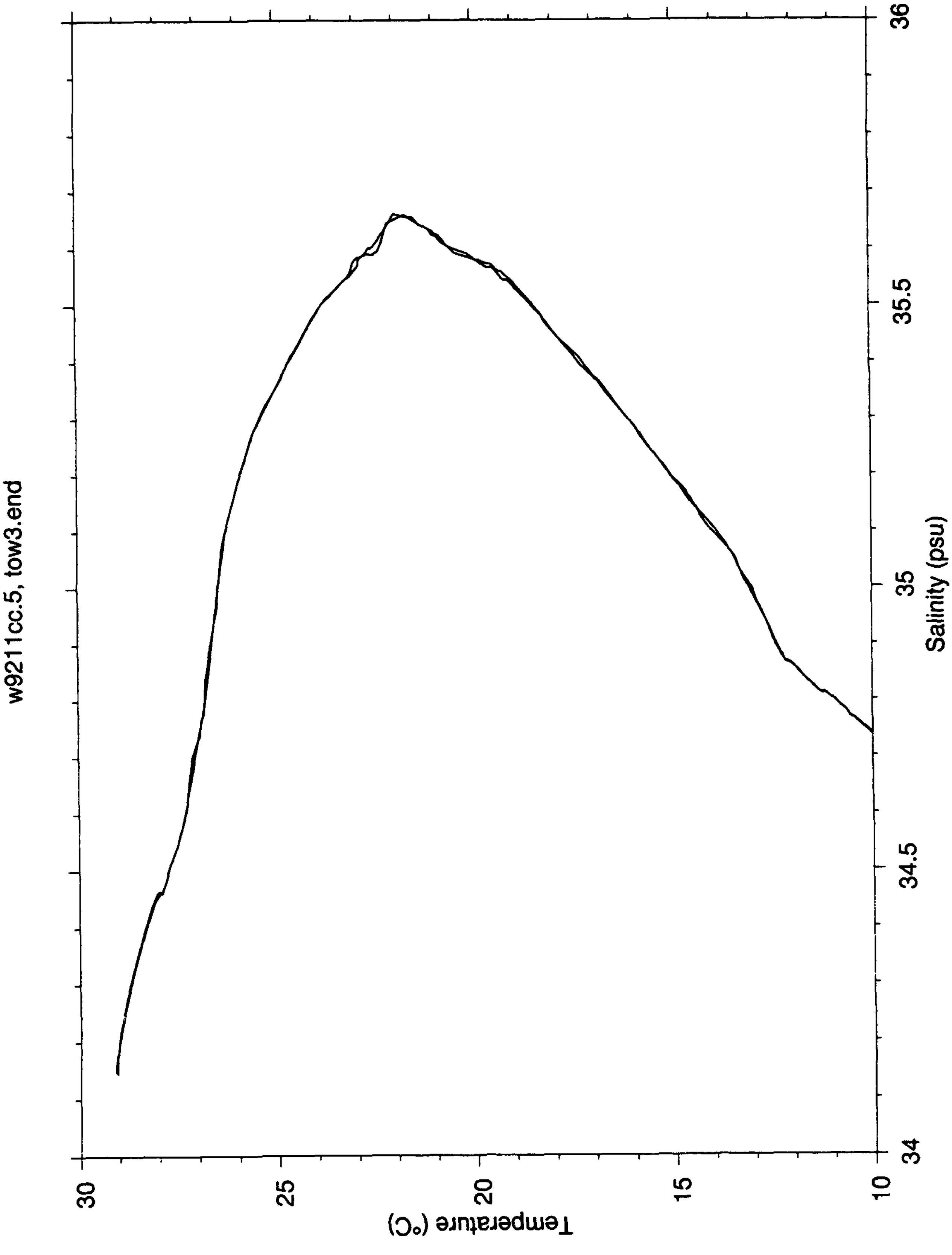
T-S Diagrams from CTD and Seasoar

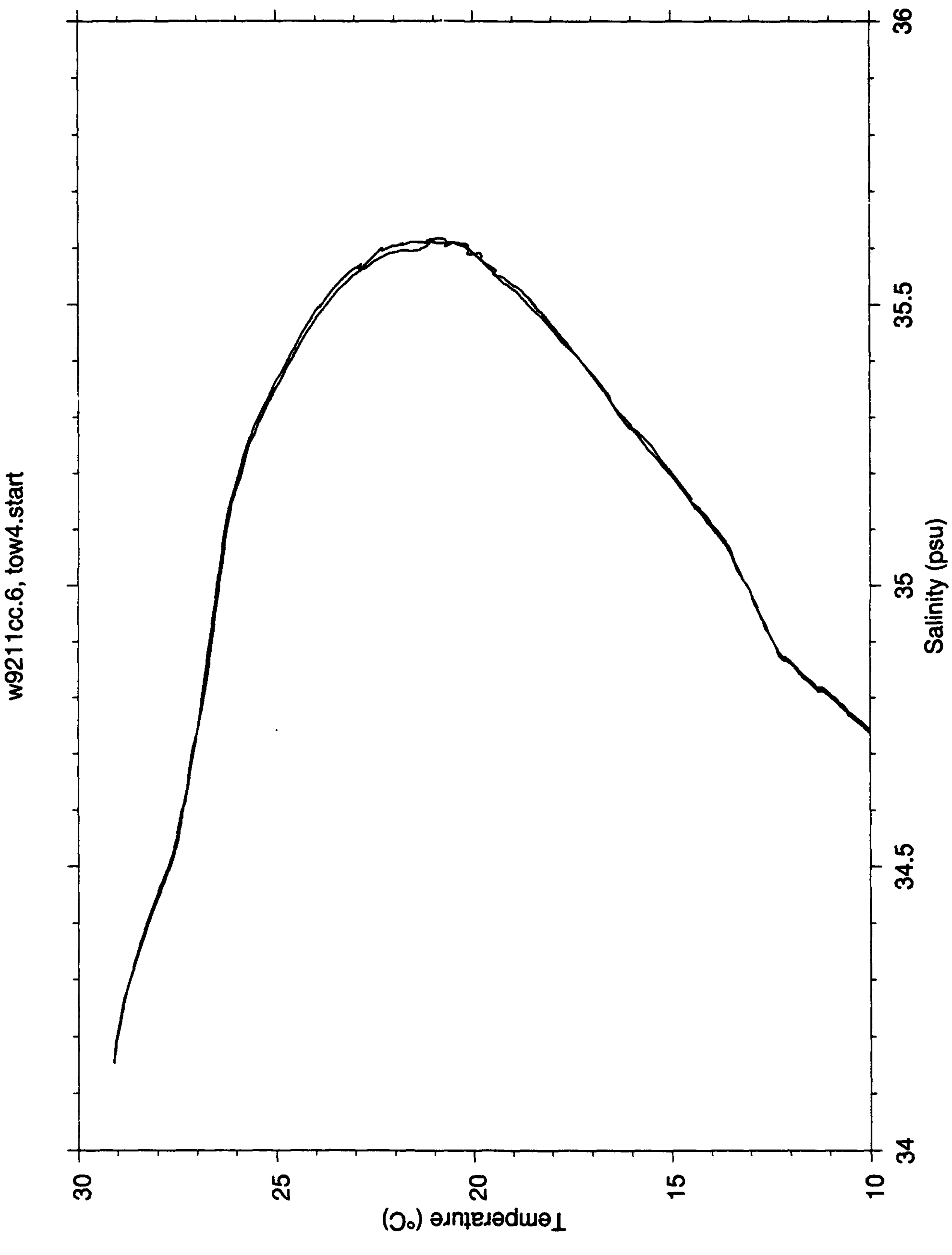
at Start and End of Tows 2-6.

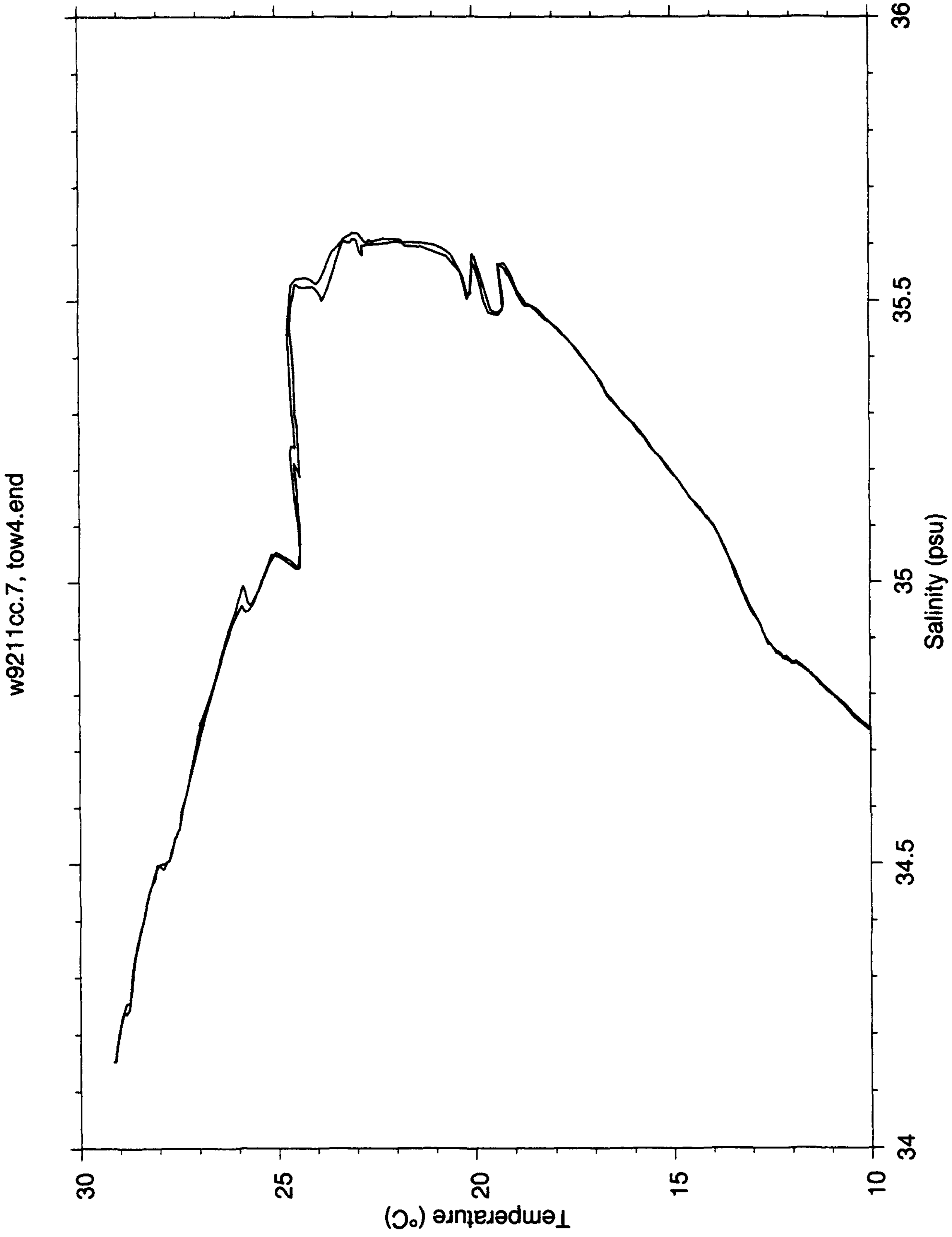

w9211cc.2, tow2.start
Temperature (°C)
30
25
20
15
10
Salinity (psu)
34
34.5
35
35.5
36

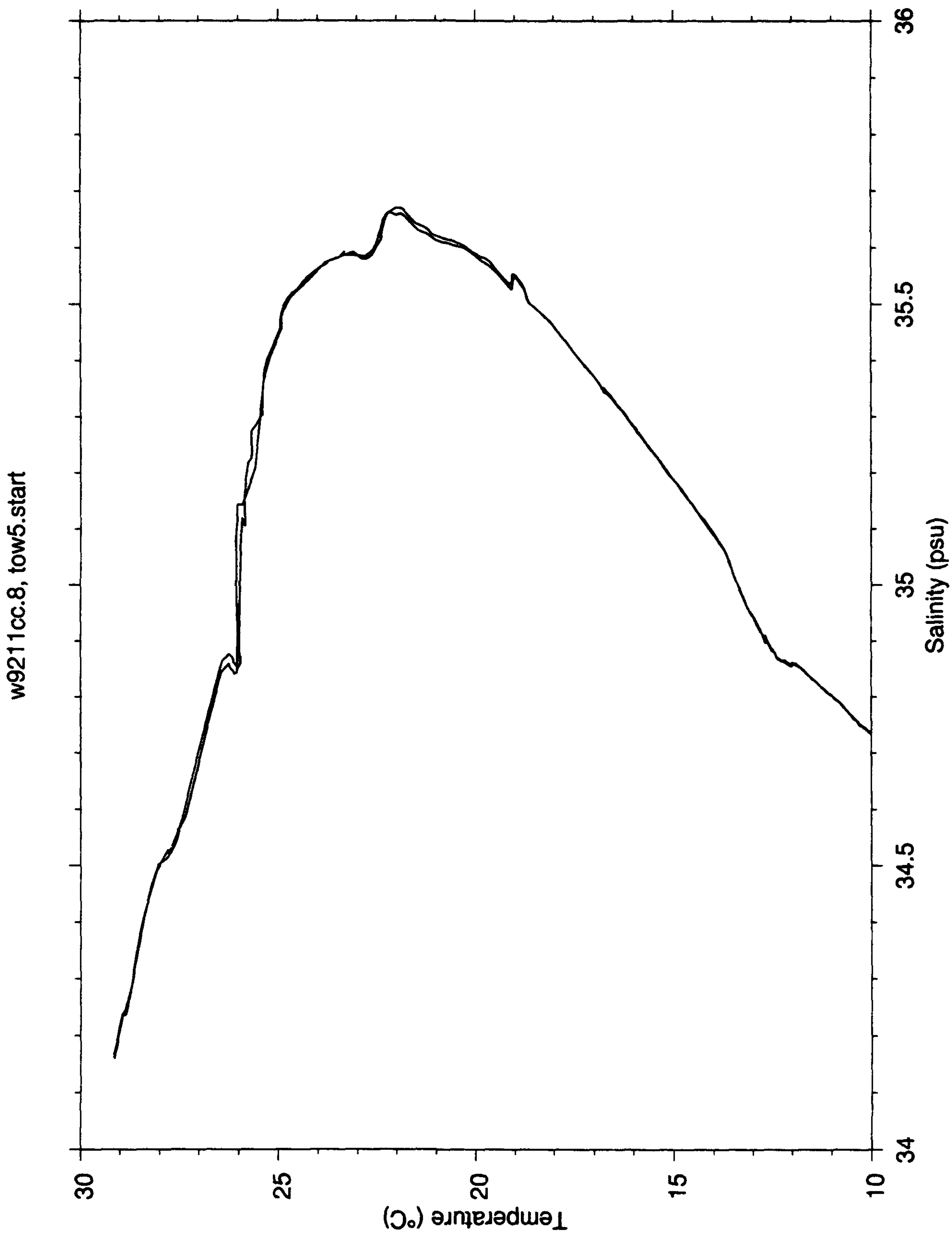

w9211cc.3, tow2.end
Temperature (°C)
30
25
20
15
10
Salinity (psu)
34
34.5
35
35.5
36

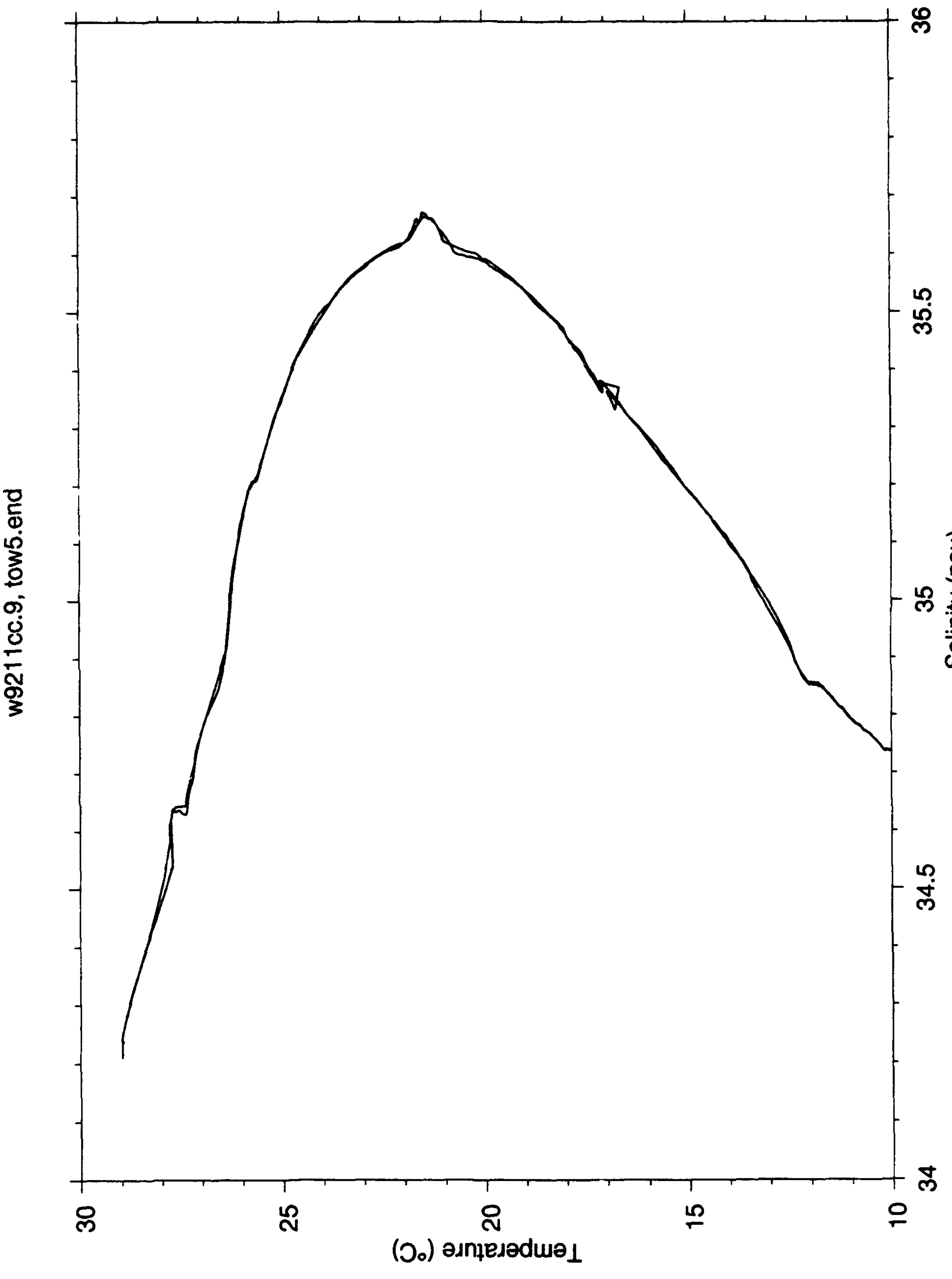

w9211cc.4, tow3.start
Temperature (°C)
30
25
20
15
10
Salinity (psu)
34
34.5
35
35.5
36

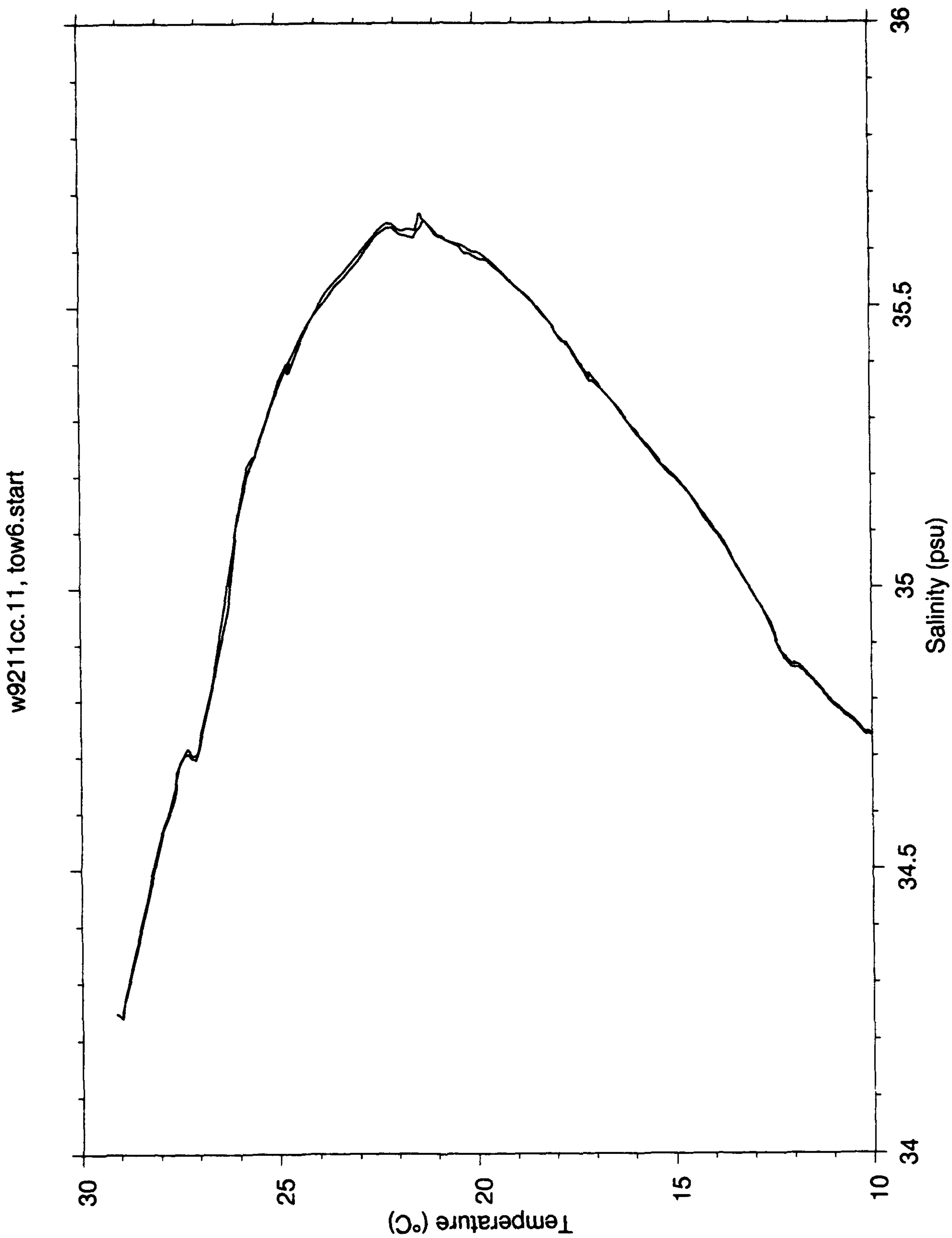

w9211cc.5, tow3.end
Temperature (°C)
Salinity (psu)
30
25
20
15
10
34
34.5
35
35.5
36


w9211cc.6, tow4.start
Temperature (°C)
30
25
20
15
10
Salinity (psu)
34
34.5
35
35.5
36


w9211cc.7, tow4.end
Temperature (°C)
30
25
20
15
10
Salinity (psu)
34
34.5
35
35.5
36


w9211cc.8, tow5.start
Salinity (psu)
34
34.5
35
35.5
36
Temperature (°C)
30
25
20
15
10


w9211cc.9, tow5.end
Temperature (°C)
30
25
20
15
10
Salinity (psu)
34
34.5
35
35.5
36


w9211cc.11, tow6.start
Salinity (psu)
34
34.5
35
35.5
36
Temperature (°C)
30
25
20
15
10

w9211cc.12, tow6.end